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JET ENGINE TECHNICIAN

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Volume 3

Maintenance Information for the Technician

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Air University

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Preface

IN THIS VOLUME, you will study proper maintenance practices of jet engines installed in current bomber and fighter aircraft. This course also presents maintenance information on small gas turbine engines installed in ground power equipment.

As a jet engine technician, you are expected to know the purpose and arrangement of jet engines; how to perform operational checks and make adjustments; how to inspect jet engines and related equipment; how to repair, adjust, and service jet engines and their components; how to perform bench and functional checks of jet engines; how to perform jet engine modifications; and how to troubleshoot jet engine malfunctions.

The purpose of the training materials in this volume is to help you attain the knowledge specified in your Specialty Training Standard (STS). The text will discuss how this knowledge is used on the job, but it does not explain how to perform each task; you will learn that through the proficiency (on-the-job) portion of your training. The text discusses many jobs performed on jet engines and their systems, but you must refer to the appropriate technical manuals for specific maintenance procedures on the engines you work on.

Foldouts 1 and 2 are printed and bound in the back of the volume. Whenever you are referred to one of these, turn to the back of the volume and locate it.

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Code numbers appearing in figures are for preparing agency identification only and should be of no concern to the student.

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This volume is valued at 27 hours (9 points).

Material in this volume is technically accurate, adequate, and current as of April 1981.

Contents

NOTE: In this volume, the subject matter is developed by a series of student-centered objectives. Each of these carries a three-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see whether your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Related Engine Maintenance

HAVE YOU EVER heard someone ask, "Why do they do it this way? Why don't they do it like this?" and then go on to explain his idea of how the work could be done better? It is rare to find a case where methods have reached perfection. A better way of doing work almost always can be found.

To help you to better understand your role as a maintenance technician in the overall Air Force effort, let's us review the objective of maintenance. Briefly, it is to keep all equipment in a serviceable status. Presently, maintenance activities are finding it more and more difficult to keep pace with the many advances in material and the consequently improved performance of Air Force equipment. At present, maintenance is faced with the problem of just keeping up with these gains. Further, additional attention must be given to technological progress, so that maintenance activities may be set up to meet present needs and be prepared for further advances.

Since the objective of maintenance is to keep all equipment in serviceable status, you, as a supervisor, should take the preliminary steps to increase the expediency and the quality of maintenance. In this chapter, we grouped areas that are common to all jet engines. Such topics include special tools and maintenance stands; engine plumbing, accessories, and components; spectrometric oil analysis; and engine bearings.

With this in mind, we shall proceed with the business at hand, which is preparation for engine disassembly.

1-1. Special Tools and Maintenance Stands

Before starting work on any engine, you must follow certain procedures. All work must be done in a safe manner so that your workers will not be injured or cause damage to the engine. In addition to doing your own required work, you must indoctrinate your workers in the proper selection and use of special tools and maintenance stands. Examine the items carefully in the segments which follow.

400. State the general name of tools used for a specific purpose, your main source of information about tools, and specify tools handling procedures.

Special Tools. Handtools are needed to remove engine parts. Without the proper equipment or tools, your workers would be handicapped. Many parts cannot be removed without their own special tools. These different types of tools, each used for a specific purpose, are called special tools. They are designed to do a specific thing and, thus, to make your job easier.

Locating special tools in the TO. In the intermediate maintenance technical orders (TOs), all special tools needed to do each job are listed by both their function and special tool number. Each special tool is listed within its functional tool group. The functional tool groups are arranged alphabetically by the name of the engine part or assembly on which the tools in that group are used. Each of the functional tool groups are identified by a tool group number which can be cross-referenced to a numerical tool list and also to the text where the maintenance on the engine is described. There is normally a pictorial index also. The tools are listed numerically with an illustration for that tool. You can use this to aid in identifying an unfamiliar tool and in your training program for new mechanics.

Using special tools. During maintenance of the engine, the applicable –6 intermediate maintenance TO tells you the special tools that are needed or used to accomplish each task. Since most of the time you will have just one of each special tool available in the shop, they will be stored in a central location. They are not to be treated as personal property, as with your workers' handtools or as part of the consolidated tool kit (CTK). You must remember that special tools are very necessary for proper completion of work. They are, in some cases, very heavy and large. In addition, special tools are expensive and usually hard to get. Therefore, you should remind your workers to use extreme care and caution when using special tools.

Special tools should never be laid on benches or workstands, as the tools could fall on the worker, causing injury. Should special tools be left on the floor of the shop, they could be damaged beyond repair. When special tools are not in use, they must be properly stored. This means shadow boards or some other type of rack should be designed specifically to store each of these tools.

Exercises (400):

1. What is the name of tools that are used for a specific purpose?

2. Where can you find information on special tools?

3. Why should special tools not be placed on workstands or benches during engine maintenance?

4. How should special tools be handled? Why?

401. List items which are inspected on the portable hoist before use and specify correct procedures to transport an engine.

Maintenance Stands. Before starting to work on an engine, certain procedures must be followed. Many parts are bulky; heavy; and, consequently, dangerous. Therefore, as a technician, you must familiarize yourself with the correct ways to use maintenance stands.

Engine transportation trailer model 3000. The model 3000 transportation trailer shown in figure 1-1 is used independently for transporting heavy loads. In some organizations, this trailer is used to hold the engines while inspections are performed. It is constructed so that other units of the Air Logistics trailers can be coupled with it. When these matched rail trailers are coupled together, you can transfer an engine from one trailer to another by sliding the engine on rollers from the model 3000 to one of the other trailers.

The model 3000 trailer can be towed at speeds up to 20 miles per hour on straightaways and on moderate curves. Reduce the speed to 5 miles per hour on tight curves.

ALC 3110 stand. When you transfer the engine from the transportation trailer to the ALC 3110 stand, you must level the engine and the stand while you are properly supporting and positioning the engine to prevent injuries to your workers. The following is used as an example of how an engine should be leveled. All engines must be leveled when they are placed in the ALC 3110 stand. The procedures for each type of engine may differ a little from those listed.

a. Use a plumbline and establish two points directly beneath the center of the chain hoist; then establish a straight line between the points by snapping a chalkline.

b. Center the ALC 3110 stand over the chalkline (for overhead facilities only).

c. Adjust the bolts and plates on the legs of the stand.

d. Install the adapters on the rails.

e. With the engine in the flight position, as shown in figure 1-2, install the adapters on the engine and lower the engine into the stand to engage PWA–16419 adapters with the eyeholes in PWA–16418. Raise the stand intermediate case adapter assemblies to engage PWA–16415 adapters attached to the case flanges. Secure with ball lockpins.

f. Place a level on the top surface of combustion chamber rear case. Raise or lower stand intermediate case adapter assemblies to level the engine.

g. Raise inlet case, diffuser case, and turbine exhaust case adapter assemblies to engage their respective engine adapters.

h. Move the ALC stand adapter assembly inboard and align ball lockpin holes with holes in adapter; then install pins.

Portable Hoist Stand. The portable hoist stand, figure 1-3, is fastened to the engine maintenance stand by quick release pins, commonly known as safety pins or pip pins.

Securing the two stands together makes it almost impossible for the hoist to fall on your workers as they remove and replace engine parts.

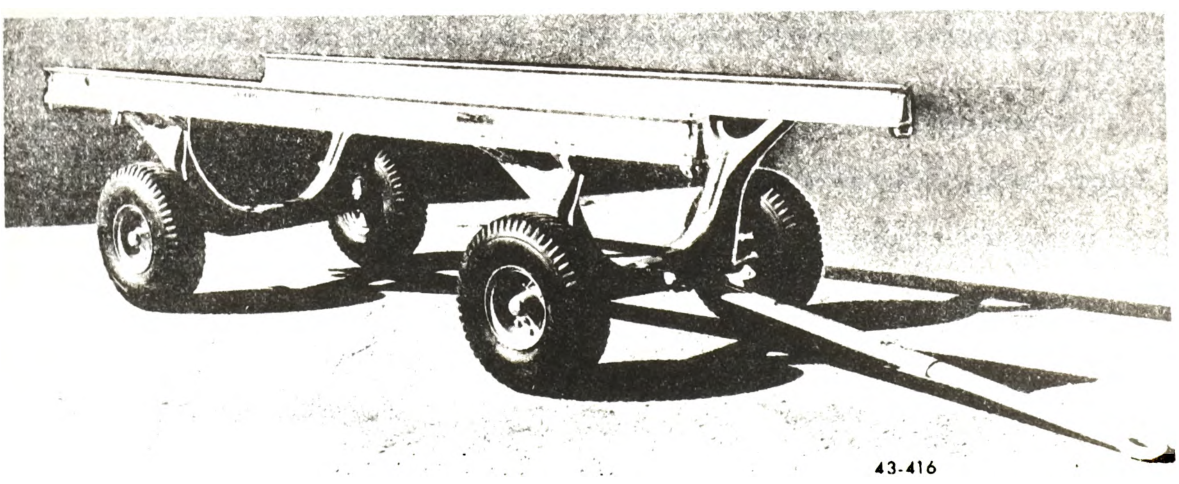

Figure 1–1. Engine transportation trailer, model 3000.

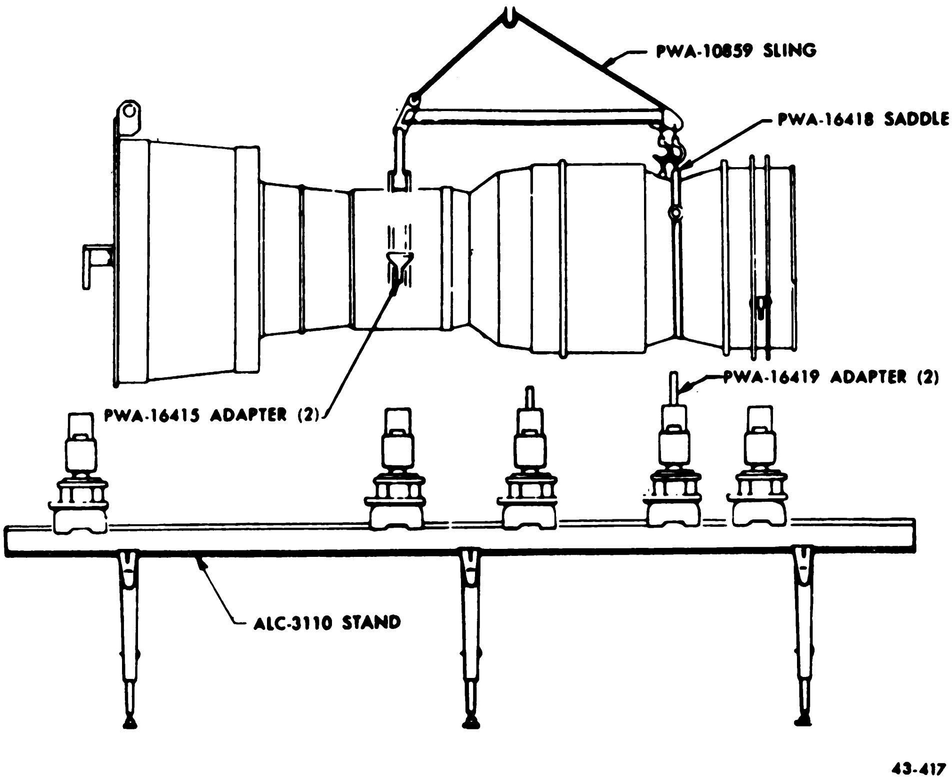

Figure 1–2. Installing engine in ALC stand.

To prevent damage to bearings, seals, and other parts, hand-operated chain hoists are used instead of electric hoists, because you have a more positive control over the amount of movement with the chain hoist. The chain hoist is moveable on the hoist stand monorail. Locks are provided to secure the hoist stand at any place on the rails of the hoist stand. This gives the worker complete control and makes it easier and safer to remove and replace parts.

Hoist stands, locks, chain hoist, and the monorail must be checked before you start to work on any engine. This means an inspection for weight capacity of the hoist stand, loose nuts or bolts, bent or damaged stand parts, and safety pin installation.

Exercises (401):

1. What is the portable hoist stand inspected for prior to use?

2. Your crew has just completed a repair action on an engine which requires the engine to be tested at the test cell. Which stand should be used to transport the engine?

3. You are transferring an engine from a 3000 trailer to an ALC 3110 stand. A portable engine hoist is being used. You use a plumbline to establish the center of the chain hoist and snap a chalkline. Was this the correct procedure to use? Briefly explain.

402. State the purpose of engine adapters and specify the causes of damage to an engine on a maintenance stand.

Engine Adapters. We cannot overstress the importance of properly supporting the engine. During all maintenance as well as during storage, the engine must be kept in proper alignment. If the engine is allowed to twist or be improperly supported, damage could be done to the engine or its parts. Removal and replacement of engine parts would become hard or impossible to do.

Whenever an engine is placed in an engine stand or transportation trailer, it must have all required adapters installed. Figure 1-4 shows an engine in an ALC stand with the adapters that are used. You will notice that the engine is well supported in the stand. Once the adapters are adjusted to level the engine, twisting and movement of the engine are eliminated.

Exercises (402):

1. What is the purpose of the engine adapters?

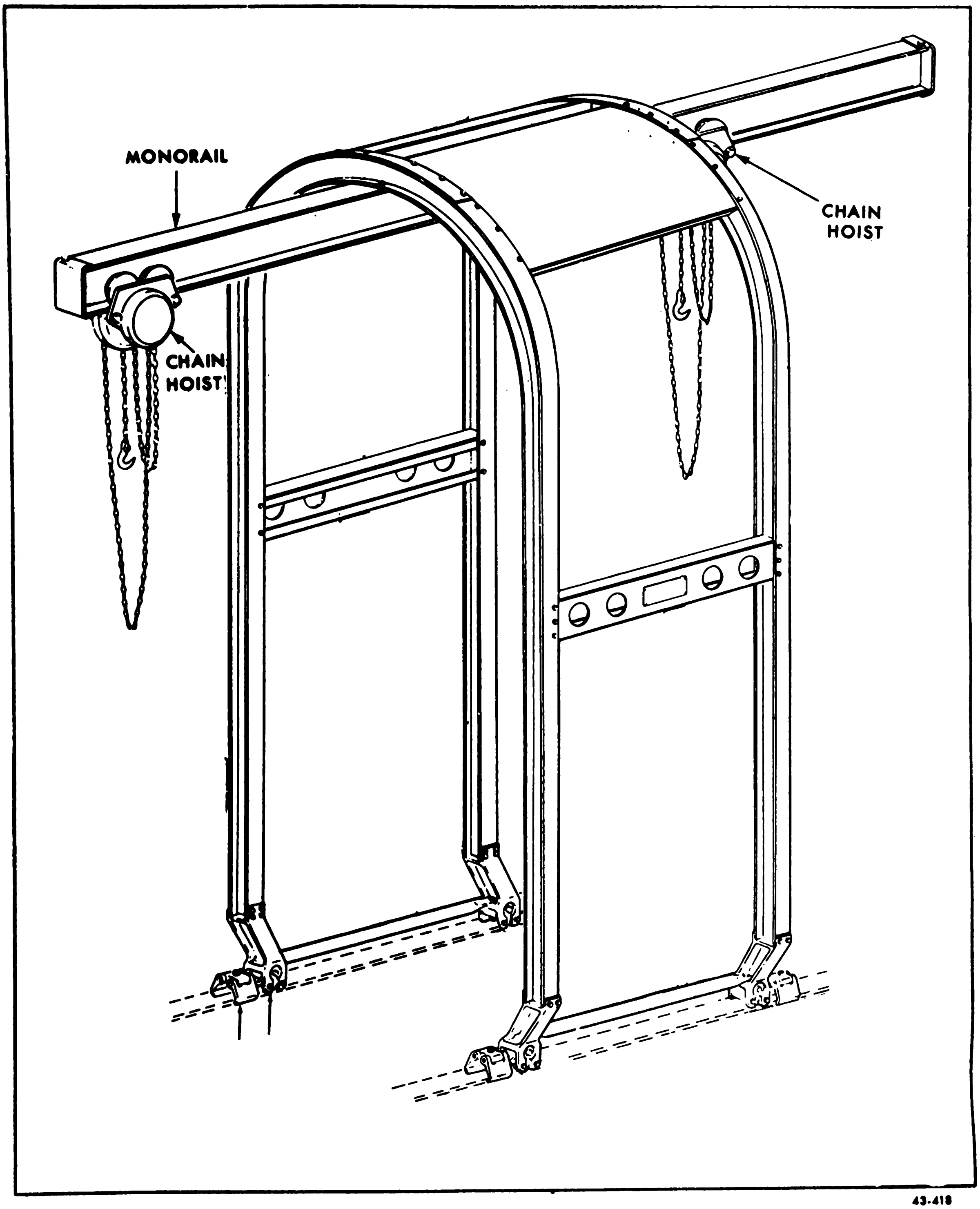

Figure 1–3. Portable hoist stand.

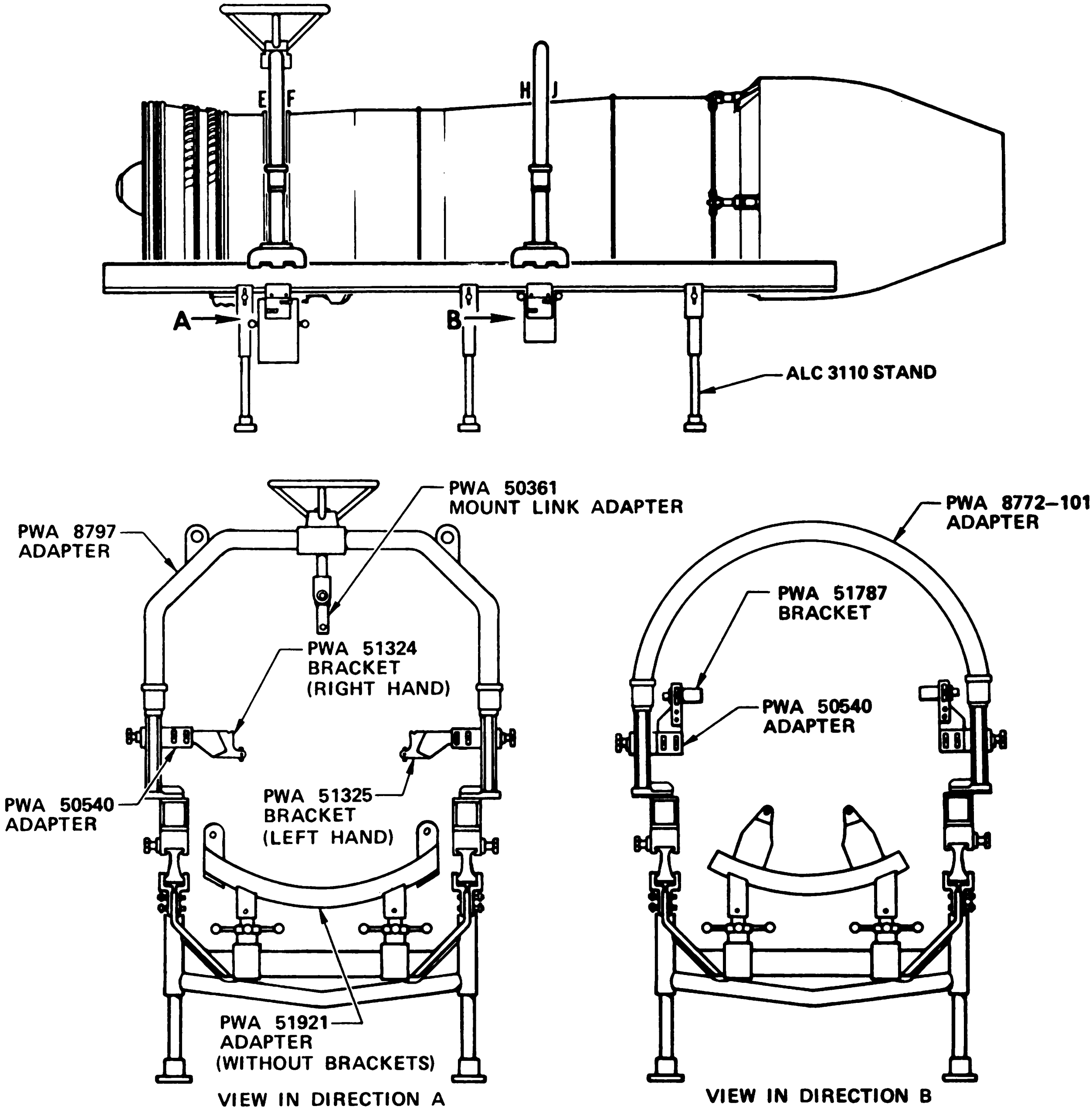

Figure 1-4. Engine mount adapters.

2. What can happen to an engine that has not been properly supported?

1-2. Engine Plumbing, Accessories, and Components

Before engine disassembly, engine plumbing and accessories are removed from the engine to facilitate complete engine disassembly. You should constantly keep in mind the safety aspects of maintenance practices and procedures that you must impart to your workers. See that they are thoroughly acquainted with the procedures outlined in the technical manuals. A thorough knowledge of procedures increases work efficiency and reduces the likelihood of injury.

403. Identify how hints are highlighted in maintenance manuals and state the advantages of maintaining a clean work area and cleaning components before you inspect them.

General Maintenance Practices. The procedures provided in maintenance manuals are arranged so that you will have a pattern to follow while a job is being performed. To eliminate duplication, general maintenance practices are usually given at the beginning of most maintenance manuals.

Notes, cautions, and warnings. As you read through maintenance manuals, keep in mind that little hints given under or by some of the symbols shown in figure 1-5 are very important. The following captions are especially important:

a. Notes. Operating procedures or conditions which must be highlighted.

b. Cautions. Operating procedures and practices which, if not strictly observed, may result in damage to equipment.

c. Warnings. Operating procedures and practices which may result in personal injury or loss of life if not correctly followed.

Work area. A clean maintenance area should be maintained at all times. A dirty area leads to contamination and subsequent engine failures.

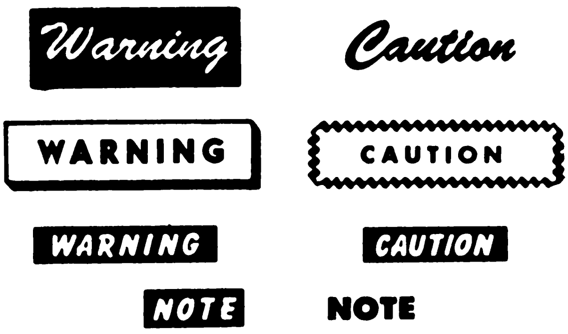

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Figure 1-5. Maintenance reminders.

a. Be sure that adequate lighting facilities are available and used. Inadequate lighting hampers production and the quality of maintenance and may cause incorrect assembly.

b. Provide a place for every part, nut, and bolt removed from the engine. Never pile or scatter them on the benches or the floor. Collecting and resorting these parts for engine reassembly delays production.

c. Never leave the turbine wheels unprotected during nonmaintenance periods. Turbine buckets may be damaged by falling tools, by rubbing against other parts, or by striking the wall. This could result in a major engine failure or at least the damaging of a serviceable engine part.

d. Never stack engine components with precision finishes (such as combustion liners) on concrete. Wooden racks, pallets, or protective mats prevent the marring and nicking that lead to cracks in the metal and leaks of exhaust gases during engine operation.

e. Keep engine openings covered during nonmaintenance periods. Dirt and other foreign materials can damage bearings, gears, etc.

General cleaning. The primary purpose of cleaning engine parts is to remove the contaminants that might conceal minor cracks and defects. These defects, if not detected, could eventually lead to engine failure. To find them, you must make a thorough inspection of the surfaces. Therefore, cleaning can be called a preinspection procedure. The quality of an engine after overhaul or repair can depend considerably on the effectiveness of the cleaning operation.

Exercises (403):

1. How are hints on maintenance procedures highlighted in maintenance manuals?

2. What is the purpose of maintaining a clean work area?

3. What is the purpose of cleaning components prior to inspection?

404. State what causes most nicks and scratches on engine plumbing and how dust caps should be installed on open lines.

Removal of Engine Plumbing. Before you disconnect any tube or hose, you may need to drain the residual fluids. In removing engine plumbing, it is essential to detach the supporting clamps before you disconnect the tubes. Using proper care will minimize damage such as nicking and scratching of tubing. Most damage of this kind occurs from careless handling of tools during engine maintenance. You must use some reliable tagging system to insure that all the hoses and lines taken off of the engine are reinstalled in their original positions. Careful identification facilitates proper replacement of parts and helps to avoid confusion and errors.

To protect open lines from contamination, use protective caps. To avoid the possibility of leaving caps installed and blocking flow, position dust caps over, rather than in, the tube ends. Tape must never be used to cover tube ends since the adhesive could cause the tube to leak when it is installed.

Exercises (404):

1. What causes most nicks and scratches on engine plumbing?

2. How should dust caps be installed on open lines?

405. State how to identify tubing systems, specify allowable limit for a dent in a straight line, and compute the allowable kink in a line with less than 500 psi operating pressure.

Tubing Systems. To aid in rapid identification of various tubing systems, study figure 1-6. Code bands of varicolored tape are attached to the tubing near the joints and at intermediate points as necessary to allow identification of the tubing system. Pay particular attention to the caption located under the color code bands.

Tubing inspection. Damage such as chafing, galling, or erosion, which causes mechanical property changes in metal tubes, greatly reduces the ability of the tubes to withstand internal pressure and vibration. Any visible penetration of the wall surface (for example, chafing of the tube) is cause for:

- Correction of the conditions that originated the damage.
- Replacement of the tube assembly or damaged section.

Any dent in a piece of tubing which is less than 20 percent of the tubing diameter is not objectionable unless it is on the heel of a short bend radius. For example, if the outside diameter is 3/8 inches, convert 3/8 to .375. Multiply the outside diameter of the tube times the allowable limit, in this case 20 percent. Take this figure and subtract it from the tube diameter. This will give you the maximum allowable dent.

The limits of dents for short bend radii are illustrated in figure 1-7 and the limits are as follows.

a. Lines which have a working pressure of 500 psi or greater. Wrinkles and kinks should not exceed a depth of 1 percent of the tube outside diameter and scratches no deeper than 5 percent of the nominal wall thickness.

b. Lines which have a working pressure of less than 500 psi. Wrinkles and kinks should not exceed 2 percent of the outside diameter and scratches no deeper than 10 percent of the nominal wall thickness.

Any tubing that exceeds the allowable limits should be rejected.

Inspection of medium- and high-pressure hose assemblies. All rubber (synthetic) hose or hose assemblies are inspected for age and deterioration prior to installation. However, Teflon hose assemblies are considered chemically inert. Therefore, they are exempt from shelf life age control. Inspect and replace installed hose assemblies according to the aircraft inspection requirements. Also, inspect for signs of deterioration. Signs of deterioration are: separation of the rubber cover or braid from the inner tube or wire braid, cracks, hardening, and lack of flexibility. Weather checking of the cover which does not expose the fabric will not cause immediate failure. However, as a safety precaution, replace hose when cracks are deep enough to expose the fabric. Hose assemblies using MIL–H–8794 or MIL–H–8788 hose must be replaced when any portion of the metal reinforcement is exposed or damaged. It may also be replaced when the outer cover becomes loose.

Exercises (405):

1. How are tubing systems identified?

2. What is the allowable limit for a dent in a straight line?

3. If you were inspecting a kink in a 3/8-inch line which carried less than 500 psi operating pressure, what is the maximum allowable measurement from the bottom of the kink to the opposite wall?

4. Which type of hose assembly is exempt from shelf life age control?

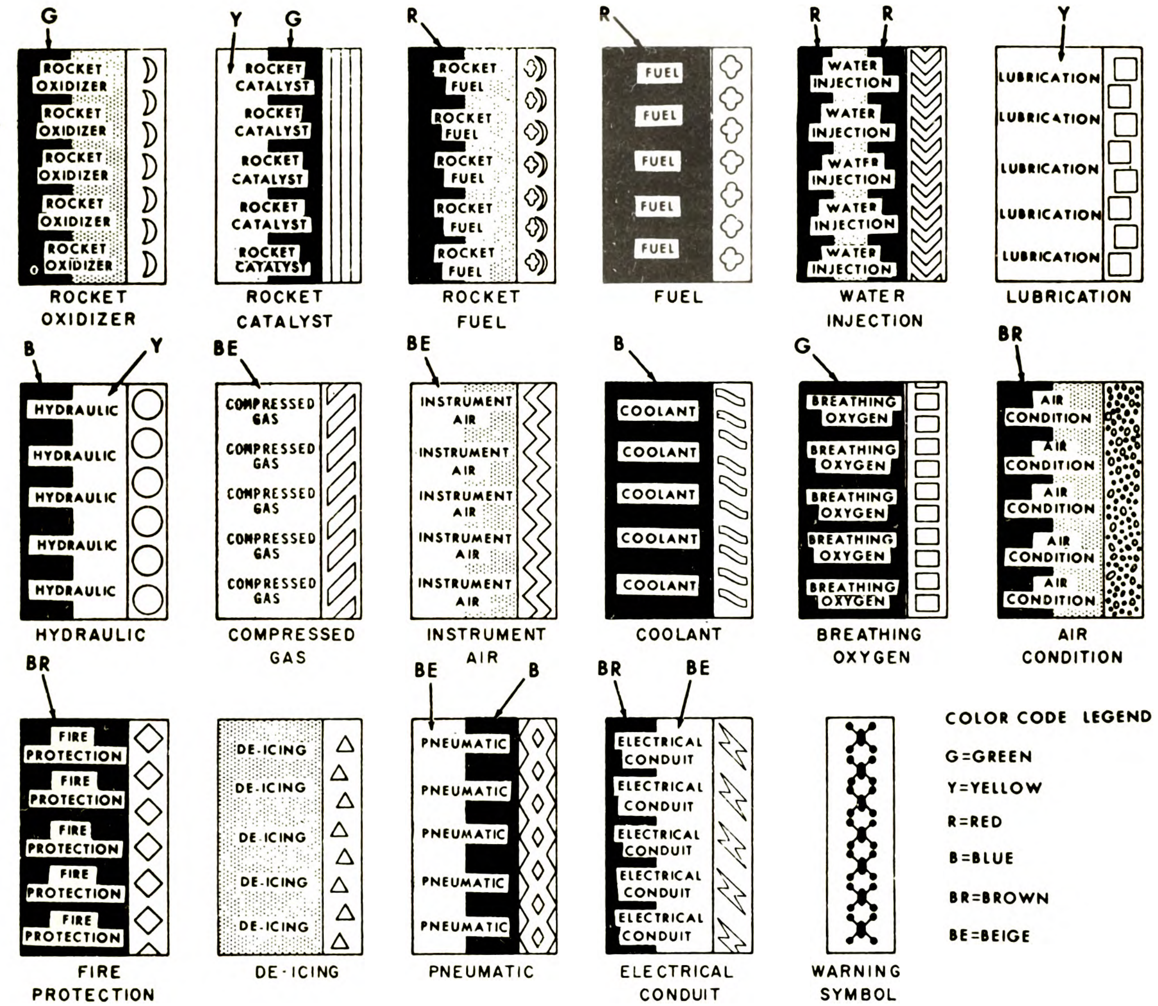
406. Specify the maximum allowable distance between clamps on engine tubing, give the specifications of a replacement hose, and explain the purpose of leaving slack in a hose attached to an engine component.

Reinstallation of Engine Plumbing. You must observe certain precautionary measures before installing engine plumbing. For example, you should always inspect engine plumbing for serviceability. Also, check internally for foreign material. To prevent vibration and chafing, you should install cushion clamps every 15 inches and as close to a tubing bend as possible. In no case should you install clamps at intervals greater than 20 inches.

When installing a flexible hose, you should follow these steps:

a. Never, under any conditions, use oil on a self-sealing hose as an aid to installation. Oil or water may be used on all other types of fuel and oil hose when installation is made; however, only oil should be used on hydraulic pneumatic hose.

b. Install hose so that it will not be subject to twisting under any condition of operation, and there is no tendency for the connecting fittings to loosen. When replacing a hose in hydraulic, fuel, oil, water injection, and pneumatic



THE ABOVE COLOR CODES REPRESENT DESIGNATION FOR SYSTEMS ONLY. FOR CODING LINES WHICH DO NOT FALL INTO ONE OF THESE SYSTEMS THE CONTENTS SHALL BE DESIGNATED BY BLACK LETTERING ON A WHITE TAPE.

SUBSIDIARY FUNCTIONS OR IDENTIFICATION OF LINE CONTENT MAY BE INDICATED BY THE USE OF ADDITIONAL WORDS OR ABBREVIATIONS WHICH SHALL BE CARRIED ON A SECOND TAPE ADJACENT TO THE FIRST OR ALTERNATIVELY, INTERPOSED BETWEEN THE WORDS DESCRIPTIVE OF THE MAIN FUNCTION.

WARNING SYMBOL TAPES, 3/8-INCH WIDE, SHALL BE APPLIED TO THOSE LINES WHOSE CONTENTS ARE CONSIDERED TO BE DANGEROUS TO MAINTENANCE PERSONNEL, WARNING TAPES ARE TO BE PLACED ADJACENT TO SYSTEM IDENTIFICATION TAPES.

ONE BAND SHALL BE LOCATED ON EACH TUBE SEGMENT, 24 INCHES OR SHORTER. ONE BAND SHALL BE LOCATED AT EACH END OF EACH TUBE SEGMENT LONGER THAN 24 INCHES. ADDITIONAL BANDS SHALL BE APPLIED WHEN THE TUBE SEGMENT PASSES THROUGH MORE THAN ONE COMPARTMENT OR BULKHEAD. AT LEAST ONE BAND SHALL BE VISIBLE IN EACH COMPARTMENT OR ON EACH SIDE OF THE BULKHEAD.

PRESSURE TRANSMITTER LINES SHALL BE IDENTIFIED BY THE SAME COLORS AS THE LINES FROM WHICH THE PRESSURE IS BEING TRANSMITTED.

FILLER LINES, VENT LINES AND DRAIN LINES OF A SYSTEM SHALL BE IDENTIFIED BY THE SAME COLORS AS THE RELATED SYSTEM.

TAPES SHALL NOT BE USED ON FLUID LINES IN THE ENGINE COMPARTMENT WHERE THERE IS A POSSIBILITY OF THE TAPE BEING DRAWN INTO THE ENGINE INTAKE. FOR SUCH LOCATIONS, SUITABLE PAINTS, CONFORMING TO THIS COLOR CODE, AND WHICH HAVE NO DELETERIOUS EFFECT ON THE MATERIAL USED FOR THE LINES, SHALL BE USED FOR IDENTIFICATION PURPOSES. IN THESE CASES THE GEOMETRICAL SYMBOLS MAY BE OMITTED.

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Figure 1–6. Color coding for tubing and hoses.

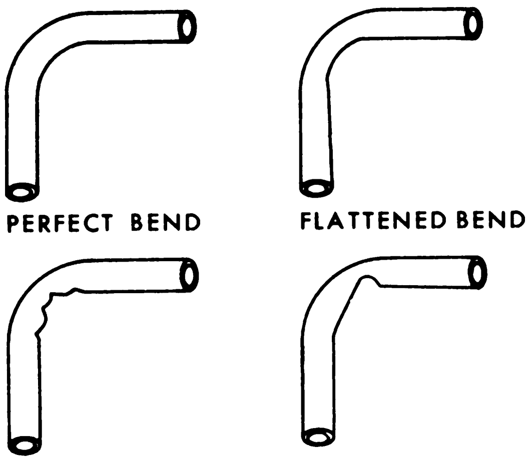


Figure 1–7. Tubing bends.

systems, the hose which is installed should be a duplicate of the hose removed as to length, outside diameter, inside diameter, material, type, and contour unless otherwise directed.

c. When bends are required for installing hoses in fluid systems, the radii shown in table 1-1 should be the minimum radii maintained at all times for fuel, oil, and coolant systems. A radius larger than the minimum allowed is preferred.

d. When hose is installed through holes in brackets or when supporting clamps are used, there must be no reduction in the diameter of the hose. If this condition is present, the flow will be reduced and damage to the hose may occur.

e. Support a hose at least every 24 inches. Closer supporting clamps are preferred. Support flexible lines so that they will not cause deflection of the rigid connecting lines. Flexible hose between two rigid connections may have excessive motion restrained where necessary, but should never be rigidly supported.

f. Eliminate chafing by using suitable bulkhead-type grommets or cushioned clamps and insuring there is adequate clearance.

g. Where hose connections are made to an engine or to engine-mounted accessories, install the hose so 1½ inches of slack or an adequate bend is provided between the last point of support and the attachment of the engine or accessory. This prevents the possibility of the hose being pulled off the nipple due to engine movement.

h. Whenever a length of hose is connected to the engine with a hose clamp, firmly support the hose in a manner that will prevent vibrational and torsional strain on the hose connection. Whenever possible, place the support approximately 3 inches from the engine connection.

i. Whenever possible, install hose so all markings on the hose are visible.

Exercises (406):

1. What is the maximum allowable distance between clamps installed on tubing?

2. When replacing a hose, what should be taken into consideration about the replacement hose?

3. What is the purpose of leaving 1½ inches of slack in a hose which connects to an engine component?

407. State where to locate information for installing engine buildup kits and associate forms and terms relating to buildup kits with their purposes or description.

Engine Accessories. When a jet engine is manufactured, it does not have all the accessories that are necessary for its

TABLE 1–1

MINIMUM BEND RADII OF HOSE FOR FUEL, OIL, AND COOLANT SYSTEMS

HOSE (MILITARY SPECIFICATION NO.)	SIZE	CORRECT RADII
MIL-H-8794 (MIL-H-5511)	All	See AND10090
MIL-H-7061	Up to and including 1-1/4 inch inside diameter	R = 6 x inside diameter
MIL-H-7061	Larger than 1-1/4 inch inside diameter	R = 12 x inside diameter
MIL-H-5593	All	R = 12 x inside diameter
MIL-H-6000	All	R = 12 x inside diameter
MIL-H-7938	All	R = 12 x inside diameter

operation in a specific aircraft. The basic engine can be adapted for use in various aircraft or positions on an aircraft. Some of the accessories which are required for aircraft and engine operation, no matter which aircraft or engine they are installed on, are furnished by the engine manufacturer.

B–1 accessories. B–1 accessories are furnished by the engine manufacturer and are part of the basic engine. Their part numbers are located in the engine illustrated parts breakdown. Examples of the accessories furnished by the engine manufacturer are fuel pumps and fuel controls.

There are many engine manufacturers who build jet engines, and obviously each engine does not have the same accessories. In order to determine if a certain engine has all the B–1 accessories installed, you must refer to TO 2J–1–24, *Equipment Compromising a Complete Basic Gas Turbine Engine*. This TO lists all the B–1 accessories for each engine used by the Air Force. Each engine has a separate index (section) in this TO. To find all of the B–1 accessories installed on a TF–33 engine, for example, you need only to locate the appendix for the TF–33 engine in TO 2J–1–24, and you will find all of the accessories listed.

B–2 accessories. The aircraft manufacturer must purchase the basic engine from the engine manufacturer and install the accessories necessary to adapt it to the aircraft. The accessories are referred to as B–2 engine accessories. To adapt an engine to a specific aircraft, your mechanics install B–2 accessories on the engine. This is known as engine buildup. The engine buildup kit is also called a quick engine change QEC kit. It contains lines, clamps, nuts and bolts, and B–2 accessories, such as hydraulic pumps, starters, and generators. Although these parts are installed on the engine, they are still considered to be aircraft parts.

Since these items are installed during engine buildup, the part numbers can be located in the aircraft –4 and –10 TOs. Also, your mechanics must know how to remove and install buildup kits. This information can be located in the –2 aircraft TO.

Time change requirements. Some accessories, both B–1 and B–2, have a time change requirement. Accessories which have a measured service life expectancy and display an age failure pattern are valid candidates for time change requirements. This means that after a component has been operated for a certain number of hours it must be changed. AFTO Form 781E, Accessory Replacement Document, lists information of B–1 and B–2 engine scheduled accessory replacements. These intervals on time changes are established to increase the operational effectiveness of the weapon or equipment item and to reduce incidents that affect safety of flight or operational safety, or degrade success of the mission.

One of the most important facts that you as a jet engine technician should know about engine buildup is how to take credit for doing the job and how to account for time. Both these items are done on an AFTO Form 349, Maintenance Data Collention Record, which was previously discussed in Volume 2.

Exercises (407):

1. Where could you locate information for installing engine buildup kits?

2. Write the letters of the buildup situations given in column B beside the correct selections in column A. Some of the entries in column B do not match column A.

Column A	*Column B*
____ (1) B–1 accessories.	a. Accessories furnished by the aircraft manufacturer.
____ (2) TO 2J–1–24.	b. Adpating an engine for a certain aircraft.
____ (3) Aircraft –4.	c. Parts found listed in TO 2J–1–24.
____ (4) AFTO Form 781E.	d. A historical record of aircraft equipment.
____ (5) Buildup.	e. Equipment comprising a complete basic gas turbine engine.
____ (6) QEC kit.	f. A kit containing B–2 accessories.
	g. A kit containing B–1 accessories.
	h. Where the part number for a B–1 accessory is found.
	i. Where the part number for a B–2 accessory is found.
	j. Accessory Replacement Record.
	k. Used to account for time expended during buildup.

408. State why it is important to determine the causes of damage, list several common causes, and tell what may occur if such situations are not corrected.

Inspection of Engine Parts. There are a number of ways that engine parts may be damaged. Some of these are lack of lubrication, shock loading, heat, and extension of minor damage such as scratches, nicks, tool marks, and improper torque. Defects may also result from the presence of foreign material. Most damaged parts can be repaired and reused.

As a jet engine technician, you must visually inspect all parts for physical defects. Check the parts for alignment, distortion, foreign matter, looseness, out-of-roundness, sharp edges, scratches, taper, warpage, and wear. In addition, inspect the holes in cases, manifolds, pipes, and tubes for obstructions.

Check gear teeth for the correct contact pattern. Carefully check magnesium parts for smoothness and flatness. Check threaded parts for general condition.

To understand what defects to check for, you should understand what the various terms describing defects mean. A paragraph labeled "Common Physical Conditions" is listed in most jet engine intermediate maintenance TOs. It lists all the terms and defines them. It also lists the more common causes of these defects. You should determine and correct the cause of any damage. Failure on your part to correct the cause can lead to premature failure of the new or repaired part. This could cause injury to people or failure to complete the mission. Of the common defects, we will cover only bearing defects and their causes in this chapter.

Exercises (408):

1. List several causes of engine part damage.

2. Why is locating the causes of damage to parts so important?

3. What may occur if the situation is not corrected?

409. Name two methods of testing metals, tell why the Air Force uses the Rockwell hardness tester, and associate mechanical types of tests with their characteristics.

The two ways of testing and inspecting metals to determine the quality of all material or parts are mechanical testing and nondestructive testing. Mechanical testing includes the methods that exert a mechanical action the material or part. Nondestructive testing includes those methods of quality determination in which the part is not affected by any mechanical action during the testing procedures. Although you, as a jet engine technician, are only responsible for performing visual inspections, you should be acquainted with the inspection methods used to support engine reconditioning. We will briefly discuss these in the following paragraphs.

Mechanical Testing. The most reliable test of a material that is being used for an aircraft part is a situation that subjects that part to the same loads or forces that it is subjected to in actual service. This usually destroys the part or renders it unserviceable. The following are types of such mechanical tests: hardness, impact, tensile, bend, shear, and fatigue testing.

Hardness testing. Although hardness testing is a nondestructive type of test, it is usually considered as a mechanical test. Hardness testing is performed to determine the ability of a material to resist penetration and deformation. Some of the most commonly known types of hardness testers include the Rockwell, Brinell, Vickers, and Scleroscope, in addition to several special and portable types.

The Rockwell hardness tester is the most widely used in the Air Force. It tests the degree of hardness by forcing a diamond or steel ball penetrator into the part being tested. These penetrators, used with the various loads, give a large enough variety of scales so that most materials used by the Air Force can be tested. This particular type of mechanical testing is considered nondestructive. The amount of indentation made by a penetrator is ordinarily insignificant and will not adversely affect the usefulness of the part.

Impact testing. A specific impact strength or the ability to withstand the shock of a suddenly applied load is also necessary in many aircraft parts. Test this property by clamping a test part securely in an impact tester. Allow a heavy load of a specified weight to swing and strike the specimen. The amount of energy required to bend, crack, or break the specimen is indicated on a calibrated dial in foot-pounds.

Tensile testing. This testing consists of stretching a material sample to test its tensile strength, ductility, malleability, hardness, and elasticity. These properties are gaged by calculating the percent of elongation and the amount of reduction in cross-sectional area of the test specimen.

Bend testing. One of the oldest methods of determining the ductility of a metal is bend testing. The bend testing equipment may be as simple as a vise and a hammer. It may be a more complex bend testing device which clamps and bends a part while indicating the degree of bend around a metal bar called a mandrel. Bend testing is often used to test the quality of a welded joint.

Shear testing. This test is a method of testing a material under a shearing load. The metal and rivets in the aircraft structure are under a shearing load which tends to slide the metal sections over one another.

Fatigue testing. This test is a method of subjecting a part or a prepared specimen to continuous and repeated stress, bending, or vibration untill the part fails. Industry uses fatigue testing to determine the need for modifying a part to increase its service life.

Exercises (409):

1. What are the two methods of testing materials?

2. Why is the Rockwell hardness tester widely used in the Air Force?

3. Match the letter corresponding to the type of mechanical testing in column B with the characteristics in column A. All column B entries may not be used.

Column A	*Column B*
____ (1) Used in checking the ductility of metal.	a. Impact.
____ (2) Subjects the items to continuous stress.	b. Tensile.
____ (3) Used to check strength, ductility, malleability, hardness, and elasticity.	c. Bend.
____ (4) Testing material which which tend to slide.	d. Shear.
____ (5) Used to check the ability to withstand shock of a suddenly applied load.	e. Fatigue.
	f. Hardness.

410. Define discontinuity, list the three essential aspects of discontinuity that guide any nondestructive testing, identify the methods of nondestructive inspection and give examples of their uses and limitations.

Nondestructive Testing. Any type of quality determination of a material or part that does not destroy or render the part useless is called nondestructive testing. The following types of nondestructive testing are discussed: magnetic particle, fluorescent dye penetrant, eddy current, ultrasonic, and X-ray.

Before going into nondestructive testing, you should know what is meant by discontinuities. A discontinuity is any interruption in the normal or regularly smooth surface of a part. This interruption may be a structural feature, such as a

corner, groove, slot, bolthole, or machining or toolmarks. It may also be a defect, such as a scratch, crack, lap, seam, or inclusion. Technically, a defect is defined as a discontinuity that interferes with the service life of a part. Nondestructive testing procedures reveal these discontinuities.

When you are engaged in nondestructive testing, keep the following factors in mind:

- An indication of a crack may not always be that of a significant discontinuity.
- A discontinuity is not always a defect.
- A defect may not always be cause for rejection of a part.

Magnetic particle inspection. Commonly known commercially as Magnaflux, this inspection has been in common use since the early 1930's. The magnetic particle inspection is accomplished by making the part to be inspected a magnet. The part is magnetized by passing an electrical current through it. If the part has sufficient ability to retain its magnetism after the current is shut off, the part becomes a permanent magnet. Then, if the part is broken into two separate pieces, (fig. 1-8) north and south poles are established in each piece as illustrated. Whether the part is broken, (fig. 1-8) or only cracked (fig. 1-9), notice that a north and south pole are established on opposite sides of the crack. Sometimes there are cracks so fine that they cannot be seen. To find such cracks, fine iron power is applied to the magnetized part. The grains of powder form a pattern around the crack in such a way that it becomes visible to the naked eye. This method of inspection will usually be done on such items as mounts and mount bolts. It is limited by the fact that the part must be made of ferromagnetic materials.

A variation of this inspection method is to add fluorescent-coated particles which, when viewed under a black light, emit a glow that increases their visibility. In this manner, defects that are hard to find are more easily located. The possibility of false indications is less with this method because there are fewer particles in the fluorescent solution than in the regular solution.

Fluorescent dye penetrant inspection. When a part cannot be magnetized, a fluorescent dye penetrant type of inspection must then be used. There will be times when this type of inspection is more expedient than other types of nondestructive testing. This type of inspection also does as good a job, quicker and for less cost than any of the other types.

The principle of penetrant dye inspection is based upon the ability of a liquid to penetrate into any crack or surface opening. In this type inspection, a greenish-yellow fluorescent dye is poured over the item being checked. The penetrant is carried into any crack or other surface opening. The excess penetrant is then rinsed off so that only the penetrant which is in the defect remains. Then with the aid of a black light each defect becomes visible to the naked eye.

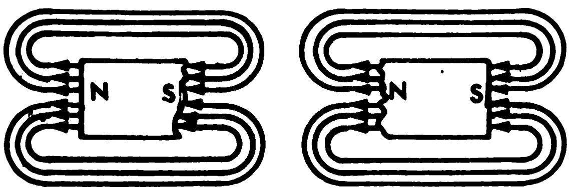
This type of inspection can be used on both ferrous and nonferrous metals. It can be used on such items as combustion liners and compression blades. One of the problems with this type of inspection is that you must make sure to clean the surface of the part properly before having it inspected by the fluorescent dye penetrant method. The part must be completely flushed of cleaning agents before you can perform a reliable penetrant test. If the part has been painted, remove all the paint. Do not remove the paint by the use of volatile paint removers; the paint remover and dissolved paint may enter discontinuities and prevent the entry of the penetrant.

Eddy current. Eddy current inspection is an electromagnetic method of identifying defects. This method uses probes of different sizes and shapes to locate both cracks and abnormal heat-treating conditions. It can be used on such components as first and second stage compressor blades to detect very tiny cracks. One advantage to this method is that items which are inspected need not be depainted. The disadvantage is that the surfaces must be smooth, flat, and very easy to get to.

Ultrasonic. The ultrasonic method uses high frequency sound waves to locate and identify defects. This method works just like sonar does for the Navy in locating submarines. A sound beam is sent into the part being inspected. The inspector can tell just how the part looks inside by watching and interpreting the signals received. This method can be used on some engine casings and rotor shafts. This method is limited by the complexity of the part since the inspector must know what a part should look like inside if a proper determination is to be made. The signals received are also hard to interpret if the person conducting the inspection had not had thorough training.

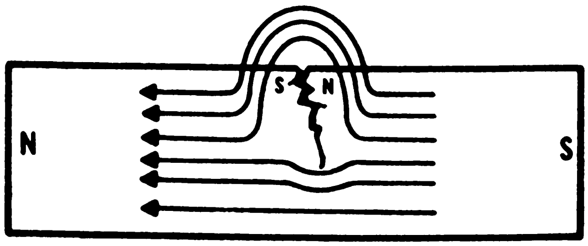
X-ray. This inspection method has a specific use in the field of nondestructive testing. This method of inspection is not intended to be used as a "cure-all" for all inspection problems, and it does not replace any other method of inspection.

X-rays are used because they enable the inspector or engineer to see the internal structure of a solid material without destroying it. X-rays are used when magnetic



43-421

Figure 1-8. Broken magnet.



43-422

Figure 1-9. Cracked magnet.

particle, fluorescent penetrant, and other types of inspection cannot locate certain types of defects. X-ray indications are produced on a photographic film by placing the part to be inspected between the film and the X-ray generating unit. The dark areas on the film show the indication of a defect such as an internal crack, lack of fusion, or gas pockets. The units for performing X-ray inspection of aircraft parts come in both portable and nonportable form. This method of inspection is both very hazardous and expensive. It is used only when no other method will do the job.

Exercises (410):

1. What is meant by discontinuity?

2. When you are engaged in nondestructive testing, what three factors should you keep in mind?

3. What limits the use of the magnetic particle inspection?

4. What is done to increase visibility during a magnetic particle inspection?

5. What type inspection method uses a black light to show fluid which is in a surface crack?

6. Is a volatile paint remover satisfactory for removal of paint before a dye penetrant inspection is performed? Explain.

7. Which inspection method can identify abnormal heat treat conditions?

8. Describe some disadvantages of the eddy current method of inspection.

9. Briefly describe the ultrasonic method of inspection.

10. How is the ultrasonic method limited?

11. How are irregularities shown in X-ray films?

12. Why isn't X-ray used more often?

411. Name what is used for smoothing painted surfaces before applying another coat of paint and list two facts that you must consider during chromic acid treatment of magnesium parts.

Surface Treating After Inspection. Most of the parts that you had to clean before inspecting should have their surfaces protected against corrosion. The specific chemicals to use are specified in the TO. The complete process of application is also specified in the TO. In cases where the parts are painted and require repainting, the TO outlines the proper method of paint removal. Be sure you use the recommended paint remover. Certain paint removers will corrode magnesium parts. If the old paint is not to be removed before repainting, smooth the surface with crocus cloth or emery cloth. Clean off all the dust before repainting.

Plug all the holes before painting the parts. Mask off all areas of a part that you do not wish to paint. The primers to use, recommended paint, drying temperatures, and drying times are all specified in the TO. Follow these instructions to produce an acceptable and durable finish on the part.

Many magnesium parts require chromic acid treatment. The solution used in this process can be extremely injurious to your skin and eyes. Breathing the fumes for too long can cause respiratory trouble. This is especially true of the solutions that are heated while being used. The exact chemicals and amounts of those chemicals to use are listed in the TO. Follow the TO procedures faithfully to obtain the best results.

Exercises (411):

1. What is used to smooth the surface of engine components prior to repainting?

2. What safety factors should you considered when chromic acid treating magnesium parts?

412. State instructions relating to stoning out nicks and dents on compressor blades, and specify what is used to mark defective areas on damaged components.

Inspecting Specific Items. Most of the foregoing instructions have been general in nature. Inspecting such items as turbine blades, compressor blades, and carbon seals requires a set of exact limits to judge the severity of any defects. These limits are all listed in the jet engine

intermediate maintenance TO under the general headings of cleaning, inspection, or repair of specific items.

There are pictures in the TO of items such as the turbine and compressor blades. These pictures show the areas of the blades and the maximum allowable damage limits in these areas. According to a current TO for a specific engine, each compressor blade of stages one through three is divided into five areas: A, B, C, D, and E. In the D area (fillet) of the blade there is no allowable damage. In the A area (blade tip radius) the damage may be reworked to a 5/16-inch radius. You should understand the importance of referring to the TO when inspecting and repairing these items. For instance, it explains that, when you stone out nicks or dents along a compressor blade, you should stroke along the longitudinal axis of the blade.

Another group of items that you will probably be required to inspect periodically is the combustion chambers. Besides being inspected at the normal inspection periods, the combustion chambers must be inspected as required by the TO when the engine has been subjected to overtemperature operation. There are full-page pictures in the jet engine intermediate maintenance TOs of the combustion chamber and the particular areas of it to be inspected. The orders also explain the limits of the permissible damage in the various areas.

Once defects in a part have been identified, interpreted, and evaluated, those that are to be repaired must be marked. Usually marking is done by circling the defective area in chalk, stenciling ink, or dye. Neve use a pencil or any marking device that contains carbcn, particularly on hot section parts. Indications found by using penetrant inspection methods can be preserved by spraying or painting with clear lacquer. Clear cellophane tape can also be used to mark indications found this way.

Exercises (412):

1. What special instruction relates to stoning out nicks and dents on compressor blades?

2. What is used to mark defective areas on components?

1-3. Joint Oil Analysis Program (JOAP)

The Department of Defense uses a program of oil analysis as a maintenance tool. This program is designed to provide maintenance people with information concerning the internal wear of engines, gearboxes, and some accessories. The program is broad in nature, but it is rather uncomplicated. JOAP is a method of analyzing oil samples to determine the identity of the small amount of metal particles worn from the oil-wetted parts. These particles are suspended in the oil and contaminate the oil system. By the use of spectrometric oil analysis, a nondestructive inspection (NDI) analyst can detect parts that are wearing too quickly. The part can then be repaired or removed from service before it actually fails. JOAP has proven that it has a place as a maintenance tool. As a jet engine technician, you should know the purpose and the procedures of the oil analysis program. You will need to work closely with the NDI laboratory technicians to insure that the program objectives are met.

413. Identify the three major benefits of the oil analysis program and provide an example of how each is achieved.

Oil Analysis Program. Spectrometric oil analysis is not a new process. It was first used in 1941 on the Denver, Rio Grande, and Western Railroad. Since then, oil analysis has grown to include many railraods, trucking fleets, buses, heavy equipment, and almost all airlines. It has been proven many times over that the use of a thorough oil analysis program will reduce maintenance costs and equipment downtime.

For an effective program, everyone involved must work together. When everyone is working together and the oil analysis program is being properly used, then three major benefits can be realized.

Improved safety. A primary consideration in any program is safety. Spectrometric oil analysis provides the capability of detecting equipment which has an impending mechanical failure. By identifying this impending failure, the equipment can be repaired before it becomes a hazard to those who operate it.

Reduced maintenance costs. Through the use of spectrometric oil analysis, overall costs can be reduced. These costs include:

- Equipment loss because of mechanical failure.
- Secondary damage caused when failure of one component causes damage to another piece of equipment.
- Over maintenance which is the reduction of the amount of work that is required to repair an item.
- Other costs related to identify failures because of design or maintenance.

Increased equipment availability. The first job of any military organization is to complete the mission. Through the use of the spectrometric oil analysis, aircraft will have a higher in-commission rate because less unnecessary maintenance is performed and the reliability rate will be increased.

Exercises (413):

1. What are the three major benefits of the oil analysis program?

2. Give an example of how each of the above benefits is derived.

414. Specify where oil samples are processed, the permanent form used to record analyses, the contact between maintenance and the laboratory, and where the wear metal guidelines are established.

Oil Analysis. Organizations without on base testing facilities will forward oil samples to the facility designated by the program manager. Each Air Force activity in the joint oil analysis program is responsible for establishing a base level program to insure that samples are taken properly and at the proper interval, identified properly, dispatched to the testing facility, and accompanied by a completed DD Form 2026, Oil Analysis Request, with pertinent information accurately entered. Analysis of suspected oil samples taken from aircraft during cross-country flights, deployment or redeployment exercises, are dispatched by the fastest means possible to the testing facility supporting the home station.

Each base appoints a JOAP project monitor to assure that the program functions properly and to serve as a contact between the laboratory on samples and the maintenance people on discrepancies.

When the mechanics complete the DD Form 2026 they must insure that each block has the correct information. This is extremely important since it affects the oil analysis results. The Action Taken, Discrepant Item, How Malfunction, and How Found blocks will be filled in only when maintenance has been performed on oil-wetted parts. The JOAP monitor notifies the laboratory when the aircraft or engine is transferred or removed from service.

JOAP Laboratories. Laboratories are responsible for testing all samples on a timely basis and evaluating the results of each sample analyzed. The laboratory keeps accurate records of each engine on the DD Form 2026 with pertinent data from the analysis and the DD Form 2026. These laboratories may be commercially operated under contract as an authorized laboratory within the JOAP. They may also be operated by either the Air Force, Army, or Navy.

All laboratories in the JOAP system must determine if a sample contains excessive wear metal. Since each engine has different limits, a guide has been printed in TO 33–1–37. This guide is used to aid the laboratory technician in making decisions. There is also a table which identifies which components could be the most likely to produce the high wear metals found in the oil

These tables have been made by analyzing countless numbers of oil samples and the resulting maintenance actions. It has been proven that oil analysis is over 99-percent accurate and, therefore, you can be sure that recommendations from the laboratory have been aided by the tables in the TO and are also going to be 99-percent correct.

Exercise 414:

1. Where are oil samples processed?

2. What form must accompany all oil samples sent to laboratories?

3. Who is responsible for serving as the contact point between maintenance and the JOAP laboratory?

4. Where will you find wear metal guidelines for your particular engine?

415. Define "wear metals" and explain the rate of production of wear metals under normal and accelerated conditions.

Wear Metals. Contact between the moving metallic parts of any mechanical system is always accompanied by friction and a consequent wearing away or transformation of the surfaces into small particles of metal. Some of these metallic particles which may be microscopic or submicroscopic in size are carried suspended in the lubricating fluids. Such particles are called wear metals. Thus, a potential source of information exists that relates directly to the condition of the system. This conclusion is developed as follows:

a. The chemical composition of the worn surfaces and the particles worn from those surfaces is the same.

b. If the rate of production of each kind of metal particle can be measured and established as being normal or abnormal, then the rate of wear of the contacting surfaces can also be established as normal or abnormal.

c. The chemical composition of the abnormally produced particles can provide clues to the identity of the parts being abnormally worn.

Production of Wear Metals. Under normal conditions, the rate of production of wear metals is constant and quite low, and the particles remain in suspension in a recirculating lubrication system. In systems such as some transmissions (constant speed drivers (CSDs) and jet engines), where depletion of the oil supply is slow and additions to the supply are seldom needed, the concentration of wear metal particles increases at a constant rate until oil change.

Any condition which alters the normal relationship or increases the normal friction between the moving engine parts, has also, the effect of accelerating the rate of wear and increasing the quantity of wear metal particles produced. Initially, this condition sharply increases the rate of buildup of wear metals in stable oil systems and causes higher than normal wear metal concentrations in rapidly depleted, frequently replenished systems. If the condition is not discovered and corrected, the deteriorating process continues, usually with secondary damage to other parts of the system, until eventually the entire system fails.

Exercises (415):

1. Define wear metals.

2. What is the rate of production of wear metals under normal conditions?

3. What conditions accelerate the production of wear metals?

416. List two factors on which oil sample integrity depends, and stipulate when oil samples should not be taken.

Sample Integrity. The value of an oil sample taken for spectrometric analysis is totally dependent on two factors: whether the oil has circulated in the system long enough to accumulate wear metal concentrations that indicate the condition of the system and whether the sample truly represents the oil circulating in the system. Ordinarily, about 5 hours of operation after an oil change is necessary to allow the circulating oil in an aircraft engine to reach equilibrium in regard to wear metals content. Oil samples taken immediately after an oil change are useless for analytical purposes. Oil samples taken from an oil tank immediately after the addition of new oil will have little or no wear metal content. The engine must be operated to the point that complete mixing of the old and new oils has taken place. On the other extreme, any carelessness whatever in the taking and handling of oil samples can cause contamination of the samples. As a result, the analysis may be erroneously high in wear metals content. An invalid oil sample is either useless, expensive, or dangerous, depending both on circumstances and whether the invalid oil sample can be recognized as such by the test laboratory.

Exercises (416):

1. On what two factors does the integrity of an oil sample depend?

2. When should oil samples not be taken?

417. Name one advantage of shorter oil sampling intervals and, given the circumstances, decide whether an oil sample should be taken before or after an aircraft's next flight.

Sampling Intervals. The operating time between intial and total failure of a mechanism can vary between a few minutes to 80 hours or longer, depending on the type of failure, kind and model of mechanism, operating conditions, and other factors. It is, therefore, obvious that the shorter the sampling interval, the greater the probability that initial failures will be detected, and that the greatest possible return is obtained by sampling after each flight of the aircraft. It is equally obvious that it would be impossible or impracticable to take samples routinely after all flights of all aircraft, both because of lack of laboratory capacity and because of the increased burden on operating maintenance personnel. Therefore, the routine sampling interval for each mechanism must be a compromise based partly on what is possible, partly on operating conditions and partly on the failure history of the mechanism. Oil in engine (CSD) or transmissions with separate oil systems should be sampled at the same time as that in the engine in the aircraft.

Oil samples should be obtained within 20 percent of the desired time when an aircraft approaches the sampling time. A long period of time between the taking of an oil sample and the receipt of a warning based on analysis of the sample lessens the probability that corrective or preventive action can be taken. Obviously, the aircraft must be operated routinely unless there is reason to suspect trouble in a mechanism. Operating the mechanism between the time you take the sample and your receipt of a warning, based on that sample, effectively lengthens the sampling interval by that additional time of operation. Lengthening the sample interval decreases the possibility of correcting the trouble before the part fails. Since the success of JOAP is dependent on the total time used in sample handling and reporting, each part of the operation must be done as soon as possible. Samples must be forwarded to the test laboratory immediately after they are taken. Analysis must be performed immediately after receipt of the samples by the test laboratory. Recommendations based on the analysis must be transmitted to operating activities without delay.

Exercises (417):

1. What is an advantage of shorter oil sampling intervals?

2. An aircraft is on a 25-hour oil sample schedule. It is scheduled to fly a 6-hour mission tomorrow. The last sample was taken at 9232 aircraft hours and the aircraft now has 9254 hours. When should the sample be taken?

418. State how the laboratory notifies the organization about an oil sample discrepancy, what action the unit takes first, and specify when the next oil sample is taken.

The laboratory, accordingly to a technical order, reports results on routine oil samples on an exception basis only. In other words, unless the laboratory suspects something is wrong with a routine oil sample, they do not forward results of the oil sample to your organization. An organization receives word about an oil sample only when the sample indicates that something is wrong.

Contaminated Oil Samples. Whenever the laboratory receives a contaminated oil sample, the laboratory telephones the organization's JOAP project monitor and recommends the action to be taken. The telephone calls that are made by the laboratory to the organization's JOAP project monitor are always confirmed by a message from the laboratory with one of the recommendations discussed in the following paragraphs.

Take oil sample as soon as possible; do not change oil. This is the most frequent message and is usually the first action taken on any unit. Receipt of this message does not necessarily mean that the engine and/or an engine unit have an impending failure. The laboratory may only be curious about one of the results from the sample. On receipt of a request from the laboratory for an additional sample, take the sample immediately after the next scheduled flight of the aircraft.

Take oil sample after every flight; do not change oil. This request is usually made after the first flight check sample indicates a high, but not excessive metal content.

Take sample at 5-hours operating time since last sample; do not change oil. This request is made after a check sample indicated that the metal content is still high, but not excessive, and the laboratory suspects something may be wrong.

Change oil and take sample after 5 hours of operation. This request is usually made after a sample has high metal content but the laboratory suspects the oil is contaminated because of high silica content or for some other reason.

Ground the aircraft; do not change oil. Take sample after ground run. This recommendation is made when a sample received contains excessive wear metals and the laboratory considers that grounding the aircraft is warranted. The laboratory will recommend ground run time before sampling.

Ground the aircraft; change oil and take sample after ground run. This recommendation is made after an oil sample has excessive wear metal and the laboratory considers grounding the aircraft is warranted. The laboratory also suspects that the oil may be contaminated and wants new oil in the unit. The laboratory will recommend ground run time before sampling.

Ground the aircraft and examine for discrepancy. If the discrepancy is not found, send the unit to the special repair activity for a "discrepancy inspection repair." This recommendation is usually sent after two or more check samples indicate excessive wear metals. The laboratory will indicate the area of discrepancy, if possible, for local examination.

Release the aircraft and return to flying status. Take an oil sample after every 5 hours of operation until further notice. This measure is usually sent after an aircraft has been grounded, the discrepancy has been found, and a check sample indicates the engine is normal. This request may also be the result of a sample that was normal after an aircraft was grounded and the oil sample returned to normal.

Return engine to normal sampling schedule. This message is sent after an aircraft has been placed on a special sampling frequency and the samples have returned to normal.

It is important for the success of the spectrometric oil analysis program that each request be promptly acted on.

Exercises (418):

1. How does an organization normally receive notification that an oil sample reflects a discrepancy?

2. What action does a unit take when a message is received on a contaminated oil sample?

3. When the laboratory recommends releasing an aircraft which has been grounded, when is the next oil sample taken?

419. Specify the two general situations that commonly require a special oil sample and tell why special care is necessry.

Special Oil Samples. Identify special oil samples by placing red tape on the shipping container of the sample bottle. These are termed "red tag" samples. Special oil samples should be taken whenever you suspect that something is wrong with an oil system, when some abnormal condition exists within the engine, or whenever any of the following conditions exist:

a. When an aircraft is involved in an accident, regardless of the cause. (NOTE: Oil samples under these conditions should be taken by any means possible with an attempt to get a clean, representative sample.)

b. Immediately before an aircraft oversea deployment or redeployment.

c. Whenever requested by the spectrometric laboratory.

d. After any indication of internal damage, such as discovery of metal particles in an engine oil sump or oil screen.

e. After any abnormal operations such as a vibration, overspeed, or other condition that might cause internal damage to the engine.

f. After the last flight before an aircraft engine enters the scheduled periodic maintenance inspection.

g. After periodic inspection, jet engine intermediate maintenance, or engine overhaul at the completion of the test cell run.

h. After each functional check flight.

i. After removal or installation of a CSD when the engine and the CSD have a common oil supply.

Take great care to insure that all oil samples are representative of the oil circulating in the oil system, otherwise, the sample will be useless. The following rules are designated to prevent contaminated samples:

a. Store unused sampling kits in a clean, closed container, such as the packaging box in which they were received.

b. Avoid contact of the sampling tube with the outside of the aircraft and engine, the pavement, and all other surfaces that might contaminate it.

c. Open the sample bottle only when ready to take the sample; replace the cap immediately after taking the sample.

d. Use a sampling tube to take only one sample and discard the tube after taking the sample.

Exercises (419):

1. Generally, when should special oil samples be taken?

2. Why should great care be taken during sampling to avoid contact between the sampling tube and any other surfaces?

1-4. Engine Bearings

You have probably noticed how rapidly an unoccupied home deteriorates. Only yesterday it was a neat, attractive home surrounded by well-kept grounds. Today, it is somewhat faded with an occasional pane of glass broken and a few scattered shingles missing. Tomorrow, it may be a sagging shell almost losing its identity amid the surrounding weeds and rubble. Through this process, nature will soon complete its task of reclaiming that which has been borrowed from it to build a house. Jet engine bearings are also subjected to the inroads of nature through corrosive action even before the parts are assembled into a finished production. If these bearings are not cared for properly, they can lead to premature engine failure. In this section, we will cover proper handling, removal, inspection, and installation of jet engine bearings and their associated parts.

420. Specify the type of gloves used to handle engine bearings and tell what is used to protect engine bearings from contamination during periods of storage.

Antifriction Bearing Handling. Proper care in handling is necessary for engine bearings to operate successfully. Rolling element bearings are manufactured to extremely close tolerances. They are particularly affected by contaminants, such as dirt and dust. Careless handling during removal, inspection, or installation can seriously reduce bearing life.

Handling of bearings should be kept to a minimum. Whenever you handle bearings, use either synthetic rubber gloves or nylon mesh gloves with polyethylene palms and fingers. If these types of gloves are not available, use cotton gloves providing you change them frequently. This is to preclude the possibility of gloves becoming sweat soaked.

You should use extreme care in handling bearings or their parts. Any audible metallic clicking caused by contact between parts of the bearing indicates the bearing is possibly damaged because of rough handling and is cause for bearing rejection.

Bearing Storage. You should store bearings in a cool, clean, dry area. The majority of bearing defects result from contamination. Dirt is made of countless numbers of diamond-hard particles. These, mixed with lubrication, make a lapping compound. Thus, the revolving action of rolling elements gradually grinds away the bearing parts. To prevent such damage, you should take every precaution to keep bearings clean at all times. Five such preliminary precautions are:

(1) Do not remove bearings from the stockroom until the unit is ready for assembly.

(2) Do not permit bearings to lie around on workbenches unprotected.

(3) Do not remove bearings from packages until complete preparation for their installation has been made.

(4) Do not allow bearings to remain exposed unnecessarily. Cover exposed bearings with a greaseproof paper or other suitable material which will not generate lint or other forms of contamination.

(5) Never spin a bearing, whether it is dirty or clean.

New bearings are coated with a preservative by the manufacturer. Before using, you must remove this preservative and insert the bearings. If bearings are not installed immediately, you must dip them in engine oil, wrap them in greaseproof paper, and then store them in a clean area.

Exercises (420):

1. What type of gloves can you use in lieu of rubber or nylon mesh when handling antifriction bearings?

2. What do you use to protect bearings during periods of storage?

421. Name the tools needed and list the main precautions (and their purposes) in removal of bearings.

Bearing Removal. Next to contamination and improper lubrication, the greatest enemy of antifriction bearings is improper removal and installation procedures. We cannot overemphasize the use of proper tools and specific bearing removal procedures as outlined in the –6 TO of the particular engine that you are working on. Removal of antifriction bearings is usually more difficult than installation. When disassembling equipment, you should inform your workers that excessive force applied for removing of housings, covers, shafts, and other parts of equipment may impose loads on unseen bearings inside the equipment. Bearings are often damaged in this manner before the mechanic doing the task is aware of what is going on.

In most aircraft engines and accessories, the bearings are installed on shafts by press-fitting the bearing inner race on the shaft. The outer race is usually fitted slightly loose in the housing in which bearings are installed. The significance of this generally used principle of bearing mounting is that it dictates the usual procedures to be followed in bearing removal from shafts and housings. The basic starting rules for removal of antifriction bearings are as follows:

a. Obtain specific tools that are specified in applicable engine intermediate maintenance instructions for removal of a particular bearing.

b. Examine tools to make sure that they are clean and in good working order.

c. Carefully check the assembly to assure that all retaining nuts, snaprings, screws, bolts, spacers, or safety wire which may interfere with bearing removal have been removed from the shaft and housing.

d. Carefully wipe dirt and other forms of contamination from the shafts and housings to prevent it from entering the bearing during process of removal. When removing a bearing, take care to prevent damage to the bearing shaft seats or bearings housings.

e. Place the tool on the bearing carefully to prevent any damage to the bearing.

f. After the puller has been installed, check it for proper alignment. Where bearings are designed with puller grooves, check to be sure that the puller flange is properly seated in the groove.

g. Remove bearings at earliest possible stage of disassembly.

h. When a bearing is to be pressed or pulled off a shaft, apply pressure to the inner race only.

i. At the beginning of bearing removal, apply light pressure on the bearing inner race with the removal tool. Then rotate the bearing outer race and check for binding. If the bearing is binding, pressure is being transmitted through the rolling elements to the outer race. In such cases, release the pressure and properly align the removal tool. If no binding is noted, continue to apply a smooth, even pressure until the bearing comes off the shaft.

j. When the bearing is suddenly released from the shaft, do not allow it to drop on the workbench, floor, or other objects.

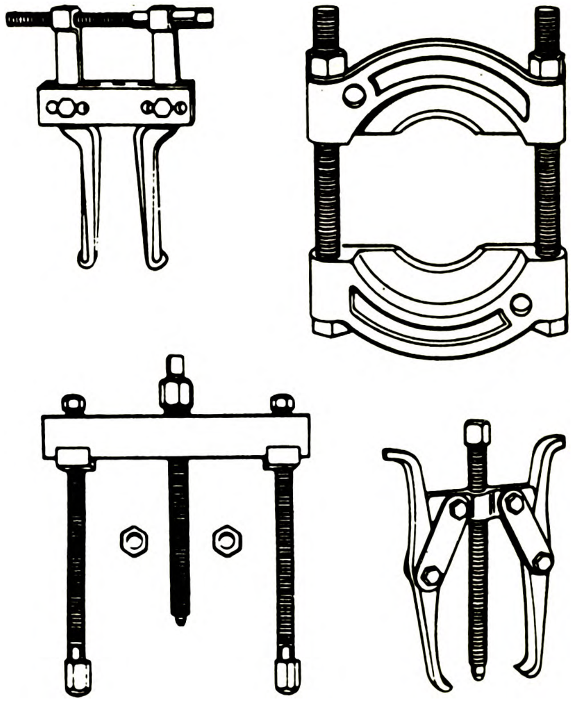
k. Be careful not to allow the removal tool to damage the shaft or housing.

l. When bearings are removed from housings, apply pressure on the outer race only.

Removal tools. Arbor press and bearing pullers are the most common bearing removal tools used. Typical bearing pullers are shown in figure 1-10. The proper selection of the correct tool to use depends on the type of installation. For example, removing bearings from blind recesses in housings may appear to be more difficult than removing bearings on shafts. But a puller having reverse claws (fig. 1-10), can be inserted through the bearing bore and expanded to grasp the outer race. When pressure is applied to the screw, the bearing is eased out of the housing without damage.

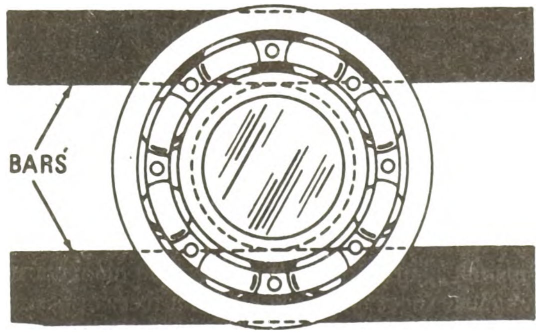
At other times, it may be necessary to use a drift pipe with an arbor press. These drift pipes can be constructed of regular iron pipe or steel tubing, provided the diameter selected fits the particular race of the bearing to be removed. The drift pipe should have a disc or plug welded into place near the top to keep dirt and other contamination out of the bearing during removal. Most bearing pullers are so constructed that special adapters can be readily fitted for a particular requirement.

Backup tools. The principle backup tools for removing bearings are steel bars and split rings. Figure 1-11 shows how two rectangular steel bars are used on an arbor press bed to assist the mechanic in pressing a ball bearing out of a shaft. A



43-424

Figure 1–10. Typical bearing pullers.



43-425

Figure 1–11. Use of backup bars.

split collar employed for a similar operation is shown in figure 1-12. In both cases, the backup tools are in contact with the inner race.

In some cases a combination of split bars and split collars can be used advantageously. Figure 1-13 shows a bearing being removed with flat bars for support and a split ring placed on top of the bars to the load of the inner race.

Exercises (421):

1. Beside arbor presses and bearing pullers, what else is used to aid in removal of bearings?

2. You are observing a mechanic removing bearing which has puller grooves. The mechanic installed the bearing puller and checked it for proper alignment, then he proceeded to remove the bearing. Did the mechanic perform the job properly?

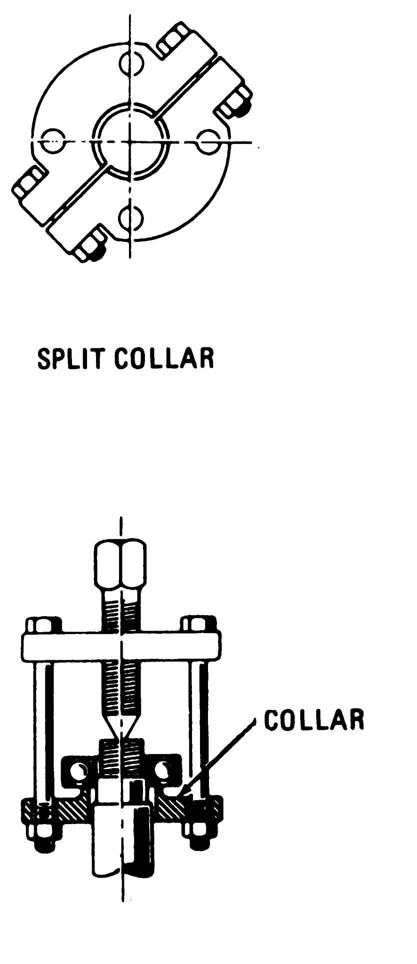


Figure 1-12. Pulling a ball bearing with a puller and split collar.

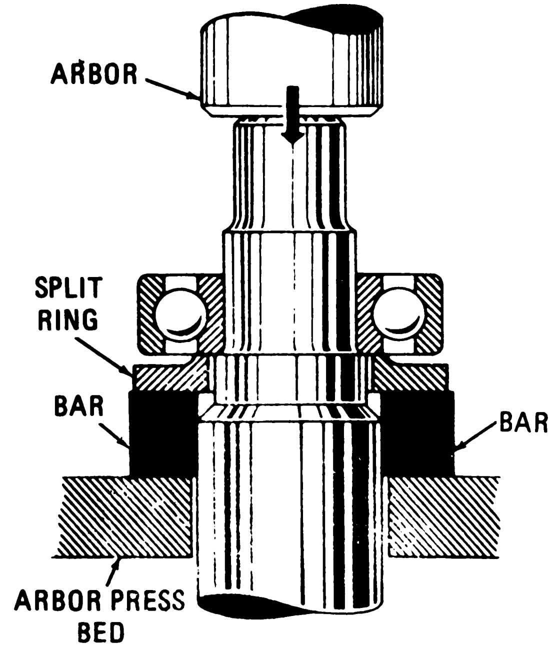


Figure 1-13. Use of flat bars and split ring in an arbor press.

3. During the removal of a bearing, you suspected the bearing of binding. You try to rotate the outer race and it's hung up. What probably caused this situation?

422. State the relationship between bearing cleaning and inspection and associate bearing discrepancies with their causes.

Antifriction Bearing Inspection. Cleaning the bearings is a very important preinspection step. The degree of cleanliness directly affects the quality of the visual inspection that you can perform on the bearing surfaces. You should establish a controlled area for this function. Such a controlled area may be a small space, room, shop, or facility where you maintain better than normal housekeeping. This area is used only for final cleaning, inspecting, lubricating, and wrapping of the bearings.

Before you clean the bearings, check them for residual magnetism. This prevents any residual sediments lying in the bottom of cleaning tanks from being attracted to the bearings. You should not intermix bearings which are separable during this process or during any other handling process. Bearings are usually matched sets and are serialized.

You should inspect the bearings for pits, nicks, scratches, grooves, bands, galling, brinelling, heat discoloration, and wear.

Pits. These are small, irregular-shaped cavities on the surface from which material has been removed by corrosion or chipping. There are two distinctive types of pitting: corrosive and mechanical.

(1) Corrosive pitting is a breakdown of the surface caused by oxidation. This type of pitting is identified by a reddish color.

(2) Mechanical pitting is caused by fragments breaking away from the operating surface. This condition is usually caused by overloading, improper clearances, or foreign particles. Like corrosive pitting, the cavities are irregular and rough but deeper in depth.

Nicks. These appear on bearing surfaces usually as a result from bearing parts striking together or being struck by sharp, hard objects during handling and processing. Nicks displace, but do not remove, metal. Nicks may be recognized by the sharp, well-defind indentation with a ridge of displaced metal adjacent to the nick.

Scratches. These are narrow, shallow marks caused by the movement of sharp objects of particles across the surfaces of a bearing. In most cases, scratches are caused by careless handling of the bearing during maintenance or by the passage of foreign particles during bearing operation.

Grooves. Circumferential grooves on rollers result from small particles of foreign material which become lodged or embedded between rollers and retainer pockets. These defects are not cause for bearing rejection, unless three or more grooves appear on one roller and can be readily felt with a 0.030-inch radius scribe.

Bands. Polished circumferential bands on balls are usually caused from continuous thrust loading during bearing rotation. Under such conditions, the balls do not change their axis of rotation. Bands of this type are not cause for bearing rejection, unless they can be readily felt using a 0.030-inch radius scribe.

Galling. It results from ineffective or inadequate lubrication on active bearing surfaces which allows metal-to-metal contact between rolling elements, races, and retainer. This condition usually occurs during sudden acceleration and deceleration. Galling may be recognized by smeared and transferred metal and heat discoloration. No form of galling is acceptable.

Brinelling. True brinelling consists of shallow indentations in the race at each roller position. This type of damage is caused by heavy shock loads or impact. This leaves a permanent depression on the roller in the contact surface.

False brinelling resembles true brinelling very closely in appearance but comes from entirely different causes. This type of damage results from continued shaft oscillation due to vibration.

Heat discoloration. When bearings have been overheated to the point of damage, the surface will appear as a bluish discoloration. The discoloration will vary from brownish blue to bluish black, depending on the severity of overheating. This failure is usually caused by lack of lubrication or by improper clearances established during installation.

In many cases, bearings are replaced unnecessarily because they do not have the appearance of unused bearings. Many used bearings have minor blemishes or apparent defects that do not affect the operation or life. In such cases, the condition probably doesn't warrant rejection.

Wear. Excessive bearing wear can usually be detected by roughness of metal on active surfaces. This is particularly true where heavy contamination has caused excessive wear. Misaligning of bearing races will also cause metal roughness at points of contact between rolling elements, retainer, and races. Bearings that have been operated under such conditions usually have excessive internal looseness as well as excessive mounting play. Wear of this type is normally accompanied by elongated retainer pockets and discoloration at contact points. Any one or a combination of these defects is normally detected by visual inspection of active surfaces. Such defects can also be detected in an assembled bearing by holding one race stationary while rotating the other. If appreciable damage has occurred on active surfaces, the bearing will feel rough and noisy. You must exercise good judgment in determining the actual bearing condition where minimum wear has occurred. Rolling element skidding also causes excessive wear in retainer pockets. Because of high temperatures that usually accompany skidding, metal will actually tear away from one surface and be deposited on another.

Always refer to the inspection requirements of the particular engine you are working on so that bearings will not be changed unduly.

Stain. Stain on bearing surfaces comes from the oxidation of oil or grease by normal operating temperatures. Stains will appear as a discoloration on the exposed surfaces, especially at the edges. The stain usually starts as a blackish color and progresses to a reddish color. Stains are not considered harmful, and the bearing may be kept in use unless acid etching in the oxidation area has progressed to a point where it can be felt with a 0.030-inch radius scribe.

Exercises (422):

1. Why is the cleaning of a bearing so important prior to inspection?

2. Match the letter corresponding to the bearing discrepancy in column B with the discrepancy identification in column A. Column B entries may be used more than once.

Column	*Column B*
____ (1) Narrow, shallow marks.	a. Pits.
____ (2) Breakdown of surfaces caused by oxidation.	b. Nicks.
____ (3) Results from continuous shaft oscillation.	c. Scratches.
____ (4) Small particles of foreign material become lodged or embedded between rollers and retainer pockets.	d. Grooves.
____ (5) Caused by oxidation of oil or grease.	e. Bands.
____ (6) This discrepancy normally occurs from lack of lubrication or improper clearances during buildup.	f. Galling.
____ (7) Occurs from continuous thrust loading during bearing rotation.	g. Brinelling.
____ (8) Caused by striking bearing parts together.	h. False brinelling.
____ (9) Occurs from ineffective or inadequate lubrication.	i. Heat discoloration.
	j. Wear.
	k. Satin.

Column A	*Column B*
____ (10) Fragments breaking away from the operating surfaces.	
____ (11) Starts as a blackish color and progresses to a reddish color.	
____ (12) Excessive internal looseness.	
____ (13) Caused by heavy shock loads or impact.	

423. State why bearing components should be suspended above the bottom of the hot oil bath tank and how the desired temperature is maintained.

Bearing Installation. Extreme care is of the utmost importance during installation of antifriction bearings in an engine. Damage incurred during installation may go undetected until the engine is in operation. You must be sure to use the proper tools for bearing installation. You must also be sure that the bearing installation procedures, as specified in the applicable engine TOs are followed to the letter. Check to be sure that the bearing is serviceable, clean, and properly lubricated before installation. Where separable bearings are used, be sure that all of the parts are a matched set. You should never attempt to install a bearing with a dirty or broken tool and don't apply unnecessary force to a bearing when it is cocked. To prevent cocking the bearing, you must check to be sure that it is properly aligned before applying pressure. Check the shaft shoulders to be sure that they are clean and free of any defects that may prevent proper bearing seating.

Heating inner races. To assemble inner races of bearings on their mating shafts, you must first expand the inner race by applying controlled bearing. Use a controlled-temperature hot-oil bath. Immerse the inner race of demountable bearings and the complete bearing assembly of nondemountable bearings in the oil bath. This is the recommended way of raising the temperature of the bearing. Do not allow the bearings to rest on the bottom of the tank. The temperature at the bottom could be much higher than that indicated by the oil bath thermostat. Also, the bearings could collect the sediment lying on the bottom of the tank. Check the shafts and bearing races for the proper size before heating the bearings in the oil bath. In this way you may be able to avoid abnormal fits.

Hot-oil tank. A heavy screen or series of rods extending about 3 inches above the bottom of the tank will support the bearing and allow dirt to settle to the bottom of the tank. The oil to use in MIL–L–7808 or heat transfer oil. It should be thermostatically controlled within the range prescribed in the jet engine technical order. (WARNING: Proper ventilation should be provided for oil baths. Excessive inhalation can be injurious to the workers. Change the oil and clean the tank as often as required. Cleanliness is an important factor here.)

Exercises (423):

1. Why should bearing components be suspended 3 inches above the bottom of the hot-oil-bath tank during heating?

2. How is the proper temperature maintained in the hot-oil-bath tank?

J–57 Engine Disassembly, Inspection, and Reassembly

AS THE USE OF LOCAL maintenance performed on jet engines increased, the type of maintenance varied from that originally allowed. Newer and better tools were needed and procured for use by both intermediate and depot maintenance. The Air Force found that it could save many dollars by repairing the engines at intermediate level as opposed to sending them back to the depot. Depot repairs unnecessarily required a considerable amount of time and money for shipment, during which time the engine was nonoperable. After receiving parts and Air Force approval in the field, the intermediate maintenance level has made necessary repairs and greatly reduced the nonoperational time of the engines. Furthermore, intermediate maintenance of jet engines has become so commonplace that engines returned to the depot are mostly because of time change or those involved in accidents. One good example of this timesaving is compressor replacement. Previously, the engine would be returned to depot maintenance if the compressor was damaged, but now the compressor can be replaced at the intermediate maintenance level.

2-1. Disassembly and Inspection of the Engine Hot Section

In this chapter, we are going to assume that an engine is in for jet engine base maintenance (JEBM). As we progress, procedures for removal, inspection requirements, and assembly steps will be discussed. We are using the J–57 as an example because its basic design and principles are still used in the F–100 engine. The engine is also used on aircraft still flying in the Air Force today. First of all, the engine is placed on a maintenance stand; then before proceeding any further, the engine must be leveled. This is to prevent undue stress being exerted on any particular part, thus causing it to bind. The leveling point on the J–57 is the top of the combustion chamber outer front case. Some engines require that a special fixture be installed when leveling, so be sure to check the technical order.

424. Name the kind of engine parts that are removed prior to engine disassembly and your source of information about removal of bolts or screws.

Engine Hardware. After leveling the engine, you then remove the QEC kit. The QEC kit consists in part of external tubing, electrical harness, and some accessories. As you remove these parts, keep small hardware such as bolts, nuts, and washers with the items they secure. You should properly identify each assembly as to the engine it was removed from. It will also speed reassembly to identify locations of attaching brackets with an acceptable marker.

No doubt, you will come to an area in the removal of the QEC kit that you are not very familiar with. Some of the parts may cause difficulty as you try unsuccessfully to remove it. If you are sure it can be removed but are baffled as to how it is done, the best route for you to follow is to refer to the power package buildup TO (aircraft—10). This TO provides the minute details in a logical sequence for removal of each part. It is possible that the one bolt that was stopping your efforts to remove the part is hidden, and this TO will tell you where it is and how to do it. Your careful adherence to the prescribed technical data will help prevent possible embarrassment, as well as give you a clear and concise procedural method to follow.

Exercises (424):

1. What are the general engine parts removed before engine disassembly?

2. Where can you find information on bolt and screw removal for the QEC kit?

425. State the primary precaution necessary in removing the turbine exhaust case, and then evaluate two hypothetical situations involving the serviceability of the exhaust cone and the oil metering jets.

Exhaust Case. To remove the exhaust case, attach the proper lifting sling to the turbine exhaust case mounting flange at 11 and 1 o'clock positions. Attach the hoist to the sling and make it taut so that it supports the turbine exhaust case. Next, remove the bolts securing the turbine exhaust case to the turbine case. Place jackscrews in the holes provided on the front flange of the turbine exhaust case and break the snap. Move the turbine exhaust case rearward, taking particular care to keep it centered. This care will

insure that the number 6 bearing, carbon seals, and spacers are not damaged. Place the case on a bench or dolly rear faceup.

Exhaust cone inspection and repair. Remove the turbine exhaust cone and inspect it for cracks and dents. Cracks in the skin may be V-grooved with a grinding wheel and welded, providing the accumulated length is no more than 6 inches. Dents are acceptable without repair if they are not over 1/4 inch in depth.

Oil metering jets. With the sump assembly removed, check the number 4½ and number 6 bearing oil nozzles for alignment to determine that the nozzles have not been inadvertently damaged or misaligned. You can check the alignment by using a 6-inch steel ruler placed along the nozzle assembly using the suction pump body as your base.

Exercises (425):

1. What precaution should be taken when removing the turbine exhaust case?

2. The exhaust cone you removed has cracks with an accumulated length of 5 inches. Can it be repaired? If so, how is it done?

3. On removal of the number 6 bearing oil suction pump, you noticed the oil nozzle was misaligned. How can you determine the amount of misalignment?

426. Differentiate between the types of combustion chamber liners needed to make one complete set and state the removal sequence.

Combustion Chamber Liner Types. The combustion chamber liner assembly is made up of four different types of liners. Each type has its own part number. Combustion chamber liners position numbers 1, 3, and 7 have the same part number and female crossover tubes. Combustion chamber liners 2, 6, and 8 have male crossover tubes and the same part number. Combustion chamber liner number 4, while it has a male crossover tube, is a different number because it has the burner pressure probe and igniter plug receptacle. The number 5 combustion chamber liner is still another number; it has the other igniter plug receptacle and it has a female crossover tube.

With the igniter plugs removed, remove the combustion chamber liners starting with number 4. Following next will be the liners with male crossover tubes. You may remove the remaining liners in any sequence.

Exercises (426):

1. What is the difference in the combustion chamber liners that make a complete set?

2. Give the removal sequence of the combustion chamber liners.

427. From a description of a combustion chamber liner, rate the liner as serviceable or unserviceable.

Combustion Chamber Liner Inspection. This inspection consists of a check for cracks, buckling, or other distortion. These distortions are caused by thermal stresses (heat expansion). The cracks and buckling are indications of stresses being relieved. Most of the actual stresses incurred will form in the early stages of engine operation and will progress at a small rate with continued engine operation. There are limitations set for these deteriorations by your applicable technical data. The limits we use in this text are not to be substituted for technical data. There are no cracks or distortion allowed on the swirl cups. You can check the distortion of the combustion chamber head by use of a locally manufactured fixture 8½ inches in diameter and 0.6875-inch thick. The bottom is machined with a handle attached to the other side. If there is excess of 0.040-inch gap between the forward face of the swirl guide and inspection plate, You should replace the combustion chamber. You must repair any crack in this area.

Burning downstream of the crossover tubes is common. This is due to a cooling air disruption which causes burning of the tabs in the outer liner. This would call for a thorough inspection of the upstream cooling air holes for an obstruction. Even if the burned tabs are within limits, you must complete this inspection. If you see cracks at the crossover tube hole, it normally indicates cause for rejection.

Exercise (427):

1. While inspecting a combustion chamber liner, you find that the head is distorted 0.035 inch and about half the liner tab is burned downstream of the crossover tube. There is a repaired crack from the crossover tube hole done prior to arrival at your station. Is the liner serviceable? Why?

428. Specify what component secures the front compressor drive turbine rotor to the front compressor and the number of turbine stages on the shaft.

Opposed to the normal belief, the turbine rotor drives the compressors. The front compressor drive turbine rotor and the front compressor are separate units in that they can be replaced separately to reduce maintenance repair costs. To

provide a connection for the two parts, the splines on the forward end of the turbine rotor shaft fit into the front compressor rear hub, which is also splined. The splines insure a snug fit and prevent slippage between the turbine rotor shaft and front compressor rear hub. A front compressor drive turbine shaft coupling, called the N_1 coupling, secures the shaft firmly to the front compressor rear hub. The turbine and compressor function, together as the dual-stage turbine rotor, use exhaust gases to drive the front compressor.

Exercises (428):

1. How is the front compressor drive turbine rotor connected to the front compressor?

2. How many stages of turbine rotors are on the front compressor drive turbine rotor?

429. State the function of the turbine nozzle, briefly describe its construction, and identify where each stage of the turbine nozzle is secured.

Turbine Nozzle. In the previous behavioral objective, we briefly mentioned the turbine wheel and that it poweres the respective compressor to which it is attached. If the turbine is to properly function, it must receive the exhaust gases to drive it. The turbine nozzle assemblies direct the exhaust gases to the turbine wheels at the most efficient angle for normal engine operation.

First-stage turbine nozzle. The first-stage turbine nozzle vanes are housed in the outlet duct assembly. It receives the exhaust gases from the combustion section directing it to the rear compressor drive turbine rotor. When installed on the engine, the outlet duct assembly is secured to the rear flange of the turbine front bearing support.

Second-stage turbine nozzle. The second-stage turbine nozzle is made up of the turbine nozzle inner seal, inner seal support assembly, and the nozzle vanes. With the unit assembled and the turbine nozzle retaining ring special tool installed on the rear face of the nozzle case, you have the assembly prepared for installation. Align the index marks on the outside diameter (OD) of the second-stage nozzle with marks on the nozzle guide vane assembly and the first-stage spacer. The inner flange of the second-stage turbine nozzle will rest on the outer flange of the turbine outer seal on the outlet duct assembly. Now install nuts and bolts with the boltheads to the rear.

Third-stage turbine nozzle. The third-stage turbine nozzle consists of three major parts: turbine nozzle case, turbine nozzle inner seal and seal support, and nozzle vanes. The nozzle vanes are positioned between the inner shroud and turbine nozzle case. When the nozzle assembly is installed on the rear flange of the turbine front bearing support, the vanes are secured by the combustion chamber outer rear case flange.

Exercises (429):

1. What useful purpose does the turbine nozzle serve?

2. Name the parts of the first-stage turbine nozzle.

3. How is the first-stage turbine nozzle mounted?

4. List the major parts of the second-stage turbine nozzle.

5. Where is the second-stage turbine nozzle secured?

6. What parts are needed to make the third-stage turbine nozzle assembly?

7. What secures the third-stage turbine nozzle vanes?

430. State how the rear compressor drive turbine rotor shaft is secured to the rear hub of the compressor and describe the mounting arrangement of the number 4½ bearing.

The rear compressor drive turbine rotor drives the rear compressor of the engine. The turbine rotor is secured to the rear hub of the rear compressor by the N_2 coupling. This coupling is placed inside the turbine shaft; therefore, it must be turned by a special wrench. The N_2 coupling has right-hand threads. The coupling is secured by the number 4½ bearing seals liner, which has left-hand threads.

Number 4½ Bearing. Between the number 4½ bearing seals liner and the N_2 turbine rotor coupling is the number 4½ bearing outer race. This is inside the rear compressor drive turbine rotor shaft. The inner race is on the outside of the front compressor drive turbine rotor shaft along with the number 4½ bearing carbon seals. Once installed, the carbon seals mate to the carbon seals liner as does the number 4½ bearing inner race inside the bearing outer race.

Exercises (430):

1. How is the rear compressor drive turbine rotor secured to the rear compressor hub?

2. Describe the number 4½ bearing mounting.

431. State the removal procedure of the first-stage turbine nozzle and the corrective action for a bowed turbine nozzle vane.

First-Stage Turbine Nozzle Removal. Remove the turbine rotors along with the second- and third-stage turbine nozzles. Also, remove the combustion chamber outer cases and the combustion liners. Now you are ready to remove the first-stage turbine nozzle. Because of the sharp edges of the airseal, you must take particular care to avoid possible injury by placing the protective covering on the sharp edges. Attach the lifting bracket to the 12 o'clock position of the nozzle guide vane assembly rear bolt circle. Then install the lifting sling on the bracket.

With a screwdriver, remove the four flathead screws securing the turbine nozzle guide vane assembly to the bearing support. Now you can hoist the nozzle assembly from the engine.

Inspection of First-Stage Turbine Nozzle. When you inspect the turbine nozzle, you can verify if the bowing is acceptable by use of a vane gage. If the gage fails to have proper clearance, you can replace the individual vane with a vane of the same classification. The vane replacement returns the assembly to serviceable status, but you need to find the original cause of the bowing. With a reasonable knowledge of engine operation, you determine that the fuel spray pattern is erratic. Locate the position of the burned vane and select the fuel nozzle cluster in this area. Most likely you will be able to visually detect the defective fuel nozzle by carbon buildup. You may be successful in cleaning the nozzle using the prescribed procedures; however, if you spray check the fuel manifold assembly, you leave no margin for error.

Exercises (431):

1. Give the removal procedure for the first-stage turbine nozzle.

2. What should you do when you encounter a bowed turbine nozzle vane?

432. Name the bearing that is housed in the turbine front bearing support and state the tolerances for dents in the turbine front bearing carbon seal housing.

Turbine Front Bearing. Previously, the text mentioned the turbine rotors, their function, and what they connect to. It is obvious that the rotors are supported by other parts. As the rear compressor drive turbine rotor shaft protrudes forward, it is encased by the turbine front bearing support which houses the number 5 bearing.

Dents without sharp edges or corners are acceptable, provided they do not exceed a depth of 1/4 inch and cover a maximum area of 2 square inches.

Exercises (432):

1. Which bearing is housed in the turbine front bearing support?

2. State the tolerances for dents in the turbine front bearing seal housing.

2-2. Removal and Inspection of the Fuel Manifold and Fuel Nozzles

The fuel system is of utmost importance in a jet engine. It governs the N_2 rotor speed and provides the energy required to make the engine operate. The fuel is delivered by way of the fuel manifold and fuel nozzles to the combustion section. Improper removal or insufficient inspection could cause disruption of fuel flow and subsequent engine damage.

433. State the primary precaution in handling the fuel nozzle clusters immediately after removal of the combustion chamber liners and in removing the fuel manifold.

Fuel Nozzle Clusters. When you remove the combustion chamber liners, use extreme care to prevent damage to the fuel nozzles. Damage to the nozzles could interrupt the fuel spray pattern, thereby causing a hot streak. Such damage could occur during maintenance by inadvertently bumping the nozzles with tools or equipment. This possibility is minimized by installing a special protector on the fuel nozzle cluster as you remove each combustion chamber liner.

Fuel Manifold. The fuel manifold consists of a primary and secondary manifold and eight clusters of fuel nozzles. The fuel manifold is covered with a heat shield to protect the primary and secondary manifolds from the intense heat of the combustion seciton. Mounting lugs are attached to the manifold for securing it to the engine. These lugs are so fixed that they help prevent warpage, both when installed and removed. During the removal of the manifold, do not pry or exert any undue pressures. Also, you should handle it carefully as you transfer it to the awaiting fixture and immediately secure it in the mounted position. Wingnuts and parallel bars retain the mounting lugs in this fixed position.

Exercises (433):

1. What is done with the fuel nozzles immediately after removal of the combustion chamber liners?

2. How is distortion of the fuel manifold averted during removal?

434. State when to field clean the fuel nozzles, and name the protective equipment required.

Fuel Nozzle Cleaning. During the normal operation of a jet engine, carbon will accumulate on the fuel nozzles in much the same manner as does on the spark plugs of your car. The same principle applies to both. Some carbon buildup does not render the part inoperative; however, it should be removed periodically. If left unattended, it could deter operation by causing hot streaks from an improper spray pattern. It is necessary to clean fuel nozzles before inspection or replacement.

The cleaning process, just as with spark plugs, requires a reasonably clean area free of dust and dirt. Also, the protective equipment for the worker doing the cleaning is comparable. When air pressure is applied or the necessary brushing is done, protective goggles or other adequate protection should be used to protect the eyes from flying dust or carbon deposits.

Exercises (434):

1. When are fuel nozzles cleaned?

2. What protective equipment is required when cleaning fuel nozzles?

435. Name the two types of brushes used to clean the nozzles and the corrective action specified for defective and clogged fuel nozzles.

Cleaning Equipment. You must remember the care and protection of the fuel nozzles during the cleaning process, as well as during removal and handling. With the fuel manifold secured into the holder, attach an air supply to prevent carbon from falling in the nozzle fuel holes during cleaning. You must use extreme caution to make certain that the metal brush does not come in contact with nozzle orifices. As the compressed air flows from the orifices, remove any carbon formation by using a stiff bristle brush or a copper or brass fine wire brush.

After the cleaning process, you need to spray check the nozzles for proper spray pattern according to technical data. While viewing the spray pattern, you notice one of the fuel nozzles is clogged and another with an improper spray pattern. In both instances, you should replace the individual fuel nozzle to correct the discrepancy.

Exercises (435):

1. What kind of brushes are authorized to clean fuel nozzles?

2. While you are spray checking a fuel manifold, you find one nozzle with an erratic spray pattern and another with no flow at all. How can each discrepancy be rectified?

436. Specify what the fuel nozzle threads are coated with before installation and tell how to repair fuel manifold heat shields.

Fuel Nozzle Installation. After discovering that a specific fuel nozzle requires replacement, you follow TO procedures. In addition to installing various parts of a nozzle in the prescribed sequence, you apply a mixture of molybdenum disulfide powder, Molykote Type Z, and compounded oil. Use a small brush and a solution thick enough to prevent any contamination of the fuel nozzle screen. Put the mixture on the threads only, and do so sparingly. This small task will help assure ease of removal on your next maintenance job.

Fuel Manifold Heat Shield Repair. In conjunction with the cleaning and replacement of fuel nozzles, you should inspect the fuel manifold heat shield for looseness. If it is loose at the time of inspection, it must be repaired. As an example, suppose the heat shield is loose adjacent to fuel nozzle cluster number 4. You should remove the present weld from the seam on the loose end and cut grooves in the heat shield to the necessary dimensions. Repair by use of a heli-arc welder and tungsten electrode. Be careful not to weld the heat shield inlet adapter forging.

Exercises (436):

1. What is put on fuel nozzle threads prior to installation of a replacement?

2. How are fuel manifold heat shields repaired for looseness?

437. Name one precaution during installation of the fuel manifold, name the gas used to pressure check the fuel nozzles and the P&D valve after installation, and give the procedure for install test equipment.

Installation of Fuel Manifold. When all repair is completed on the fuel manifold, you are now ready to install it. As you did in removal, assembly, and transportation, handle the assembly carefully to avoid distortion. The nozzles have been replaced and the heat shield repair

completed, so you take even more care to keep all the work from being wasted.

Fuel manifold and nozzle pressure check. Now the careful handling and installation is completed. The final proof of reliability is yet to come. If the primary or secondary manifold leaks, fuel outside the combustion liner could ignite, causing an aircraft fire. To be sure this does not happen, you need to make a leakage check. Freon gas is used in conjunction with a Freon gas detector. The fuel nozzle clusters are blocked off with specially designed caps and then pressure is applied. You can find any leakage with the Freon gas detector.

Pressure check equipment connection. Remove the primary and secondary fuel pressure locating lugs from the P&D valve. Remove the combustion chamber drain line from the unthreaded port. Remove the P&D valve overboard drain fitting and install typical plugs and fittings on the P&D valve. Plug the combustion chamber drain line unthreaded port on the P&D valve with a bolt and 0-ring seal in the unthreaded port and secure it by placing a C-clamp around the valve body and bolthead. Tighten the clamp sufficiently to prevent leakage. Apply 90 to 120 psi pressure of Freon gas and pass the detector pickup very slowly over the manifold assembly. Any evidence of Freon gas leakage is cause for removal and replacement of the fuel manifold with a serviceable item.

Exercises (437):

1. What precaution should be observed when installing a fuel manifold?

2. What gas is used to pressure check an installed fuel manifold and P&D valve?

3. How is the test equipment installed to leak-check the fuel manifolds?

2-3. Disassembly, Inspection, and Reassembly of the Compressor Section

It is essential for jet engine people to not only know the procedure for dismantling and inspection of an engine, but also the proper handling of engine parts throughout the maintenance process. You should also know the installation procedures with the proper torque values for nuts on different sections of the engine. Foreign Object damage (FOD) is ever present; so you should take the precaution to keep all the engine openings covered during maintenance.

438. Specify when the number 4 bearing is removed, what retains the number 3 bearing outer race, and describe how the N_2 compressor is removed from the outer case.

Number 4 Bearing Removal. The number 4 bearing supports the rear of the N_2 compressor. With the N_2 compressor removed from the engine assembly. the bearing can be removed without the required support needed in the horizontal position. If you replace the compressor, the bearing must be removed from the compressor hub before you return the compressor to supply. In addition, if one part of the double ball bearing is defective, the complete bearing must be removed and replaced with a new bearing since the two races are a matched set.

Number 3 Bearing Removal. The number 3 bearing supports the front of the N_2 compressor. To remove the inner race from the front compressor rear hub, remove the rivets and use the special wrench to remove the nut. Position the puller jaws of the puller tool behind the bearing inner race spacer and remove the bearing. You now remove the snapring securing the outer race, and remove the number 3 bearing outer race from inside the front hub.

N_2 Compressor Removal. To remove the N_2 compressor from the outer race, the procedure may be easier after the assembly is vertical. First you remove the circle of nuts on the inner diffuser case which holds the number 4 bearing in place, figure 2-1. Then remove the screws that hold the outer N_2 compressor case to the outer diffuser case, figure 2-2. Now attach lifting brackets on the diffuser case outer flange and lift the diffuser case from the compressor.

Exercises (438):

1. When is the number 4 bearing removed?

2. What is used to retain the number 3 bearing outer race?

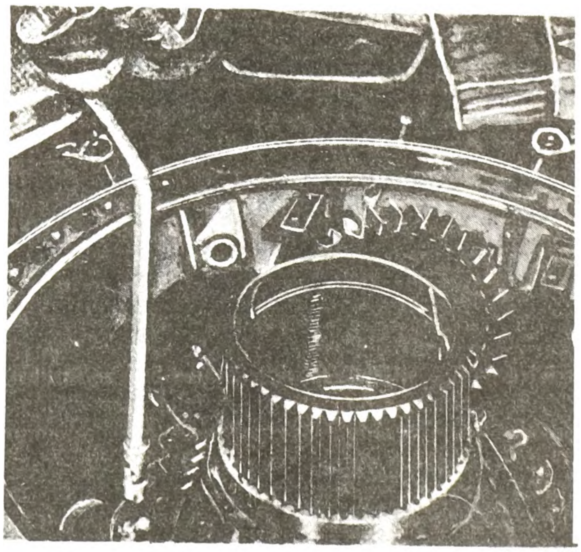


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Figure 2–1. Removing diffuser-to-number 4 bearing housing nuts.

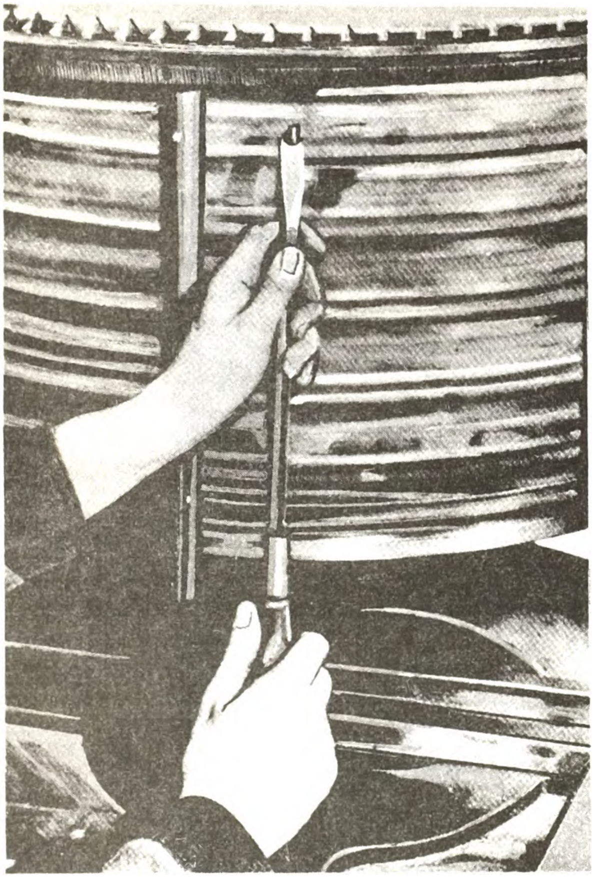

Figure 2–2. Removing rear compressor case-to-diffuser case screws.

3. How is the N_2 compressor removed from the outer race?

439. Interpret hypothetical findings on the inspections of the N_1 and N_2 compressors to rate their serviceability.

Compressor Inspection. The compressor blades and the hub of each compressor are the main inspection areas. Allowable repair is normally made only on the leading and trailing edges of the front compressor rotor blades (fig. 2-3), areas C and E only, and not on the complete blade area. If you had a single dent in the leading edge of the blade, you would not have to dress the whole C and E areas. You only have to blend the repair into the blade so the length is at least four times the depth of the injury. All blade repairs will be marked with an approved dye. Figure 2-4 shows how a dent or injury may be removed. No repair of dents is allowed on the N_2 compressor.

You must clean the hub, rivets, and tie rod cover nuts with suitable solvent. With a strong light and five-power magnifying glass, check closely for crack indications, tie rod cover nut security, balance weight security, and rivet condition. Slight looseness of the rivets is allowed except on balance weights. Missing rivets, defective tie rod cover nut, and/or hub cracks are cause for rotor rejection.

Exercises (439):

1. The compressor you are inspecting has a 1/8-inch nick in the leading edge in blade area C of the second stage of compression. Refer to figure 2-3 to see if the compressor blade can be made serviceable. What is the maximum allowable dent size?

2. While inspecting the N_2 compressor, you detect a loose rivet and a very minute crack in the hub. Is the compressor serviceable? Briefly explain.

440. Specify how carbon seals are cleaned and decide whether a particular carbon seal meets inspection standards.

Carbon Seals. To satisfactorily inspect carbon seals, they must be cleaned. Carbon solvents prove fatal to carbon seals as it can remove the impregnating agent and cause subsequent abnormal wear of the carbon element. Seals which appear to be dirty must be cleaned only by washing them with clean kerosene or by petroleum solvent spray. After cleaning, blow off excess fluid with light blasts of air. You should never wipe seals with a cloth.

During the inspection of carbon seals, look for nicks, chips, cracks, and scratches. If 25 percent of the original width of the seal face is remaining, it is acceptable. With the damage in any other area than the sealing face, it is acceptable on the following conditions:

a. There is no deterioration as evidenced by crumbling of the carbon material.

b. At least 70 percent of the normal cross section of the seal remains.

c. At least 50 percent of the surface of any damaged bearing pad remains.

d. Inside diameter (ID) scratches of less than 0.005 inch in depth or 0.010 inch in width. Cracks in any portion of the seal and defects beyond the TO wear limits is cause for rejection.

Exercises (440):

1. How are carbon seals cleaned?

2. If a carbon seal shows wear and has a chip of 70 percent of the sealing face missing, is it serviceable? Briefly explain.

MAXIMUM ALLOWABLE LIMITS—INCHES

BLADE AREA		STEEL AND TITANIUM BLADES		TITANIUM BLADES
		STAGES		STAGES
		1 THRU 4	5 THRU 9	7
	A	5/16 R	1/4 R	1/4 R
	B	1/32 D	1/32 D	1/32 D
	C	5/32 D	1/8 D	1/8 D
	D	.008 D	.005 D	NONE
	E	1/32 D	1/32 D	1/32 D

R = RADIUS

D = DEPTH

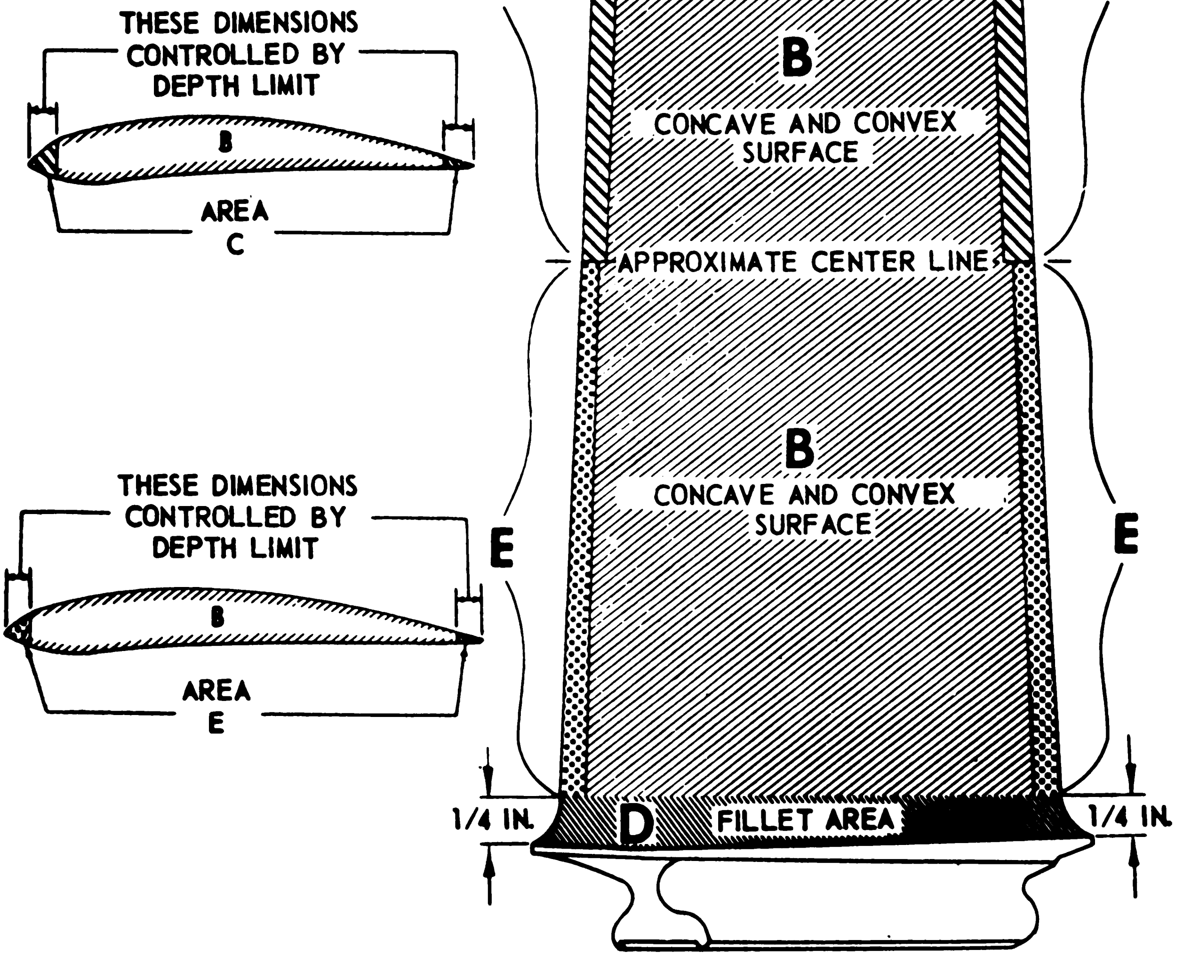

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Figure 2–3. Front compressor blade injury limits.

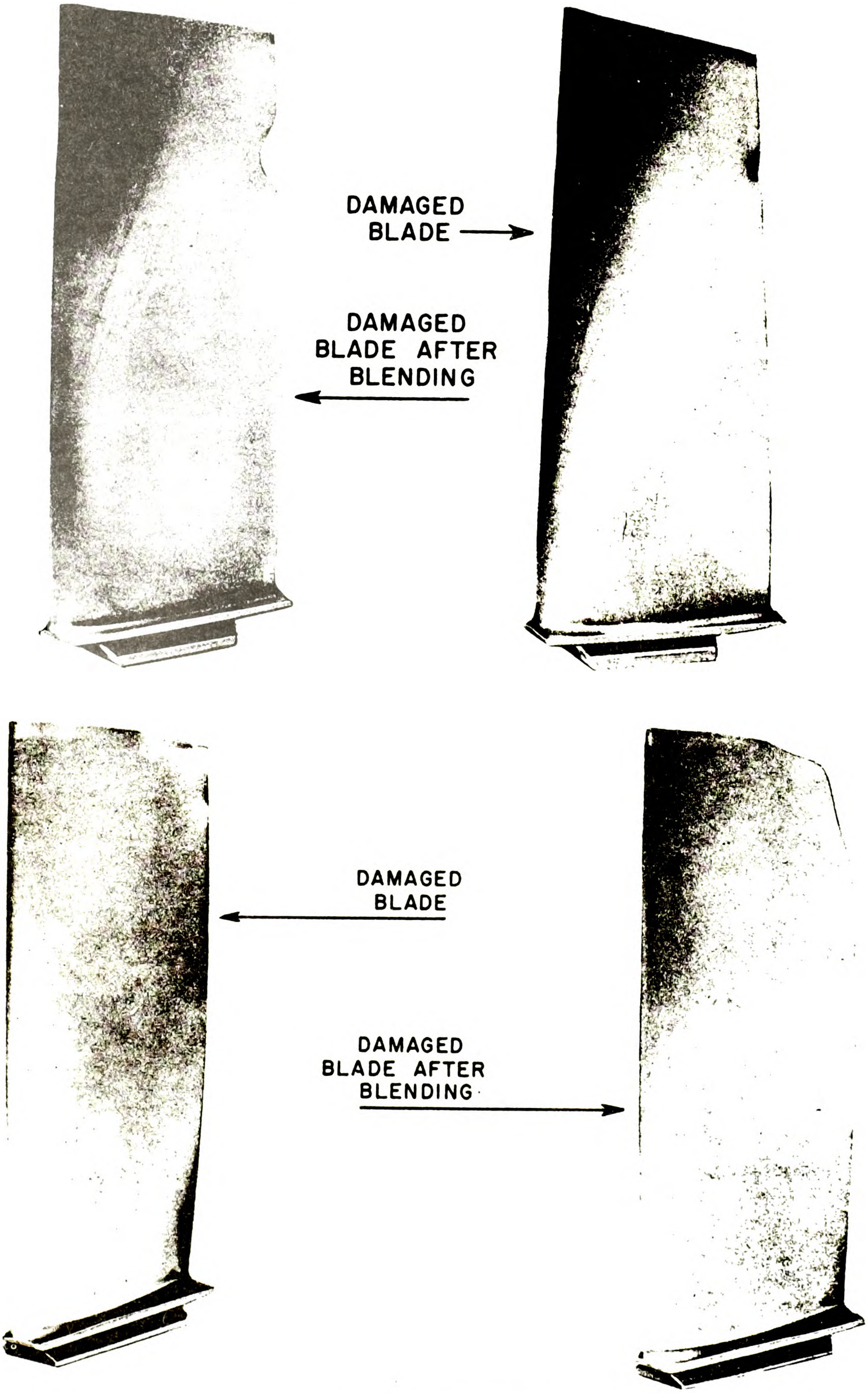

Figure 2–4. Compressor blade repair.

441. State how the number 3 bearing is installed and which cases are mated when joining the rear compressor to the front compressor.

Compressor Assembly. Before reassembly of the compressor assemblies, you must install the number 3 bearing. Heat the number 3 bearing inner race and cage in hot oil. Install the race and cage, making sure the serial number is to the front on the front compressor rear hub. The inner race is secured by the retaining nut on the rear hub. Torque as specified in technical data. You must chill the outer race before installing. Position the race, with the serial number toward the front of the engine inside the rear compressor front hub. Secure the race with the snapring.

The compressors are assembled by joining the intermediate case to the front compressor case and by secureing with the necessary hardware. Now you can attach the compressor diffuser case to the aft end of the intermediate case.

Exercises (441):

1. How should you install the number 3 bearing outer and inner race?

2. Name the mating cases for assembling the compressors.

3. What is used to secure the number 3 bearing outer race?

442. State where the number 2 bearing is installed and state the probable cause of failure of a new number 2 bearing on the test run.

Number 2 Bearing. The number 2 bearing is a double ball bearing carrying both axial and radial load. It is installed on the N_1 compressor rear hub. Should your inspection determine any part of the bearing nonserviceable, according to technical data, you must replace the complete bearing. The bearing is machined so perfect that intermixing of parts is prohibited. When installing the bearing, you must heat the inner races while the outer races are chilled before installation.

You must install the number 2 bearing oil tube straight into the oil strainer adapter. Do not tilt or cock the tube. Failure of the front compressor rear bearing may result if the tube is not properly installed.

Exercises (442):

1. Where is the number 2 bearing installed?

2. On the test run, vibration was noted in the number 2 bearing area. What could be wrong if a new bearing was installed?

443. State the purpose of an outer race spacer measurement of the number 4 bearing and the number 3 bearing runout check.

Number 4 Bearing. The number 4 bearing must support the N_2 compressor rear hub. There is a direct relationship between the bearing position and the support it affords. To assure the proper position for maximum support, it may be necessary to take the bearing outer race spacer position measurement. Anytime you change the number 4 bearing, bearing housing, diffuser case, or the bearing baffle assembly, you must also take the measurement. To do this efficiently, refer to the technical data pertinent to your engine.

Number 3 Bearing. The number 3 bearing supports the front of the N_2 compressor. It, too, must be in the correct position to maintain smooth operation. You are now concerned with the concentricity. To make a runout of the outer race, place the indicator against the inner diameter of the outer race. If runout exceeds 0.0005-inch full indicator reading (FIR), the coupling should be loosened and a radial pull of 100 pounds exerted away from the point of maximum runout. The coupling should then be retightened. If runout is less than 0.0005-inch FIR, no further action is required. If the runout is greater than 0.0005-inch FIR, you must remove the coupling and turbine, and reindex the splines and/or check the parallelism of the shaft spacer. Reinstall the turbine and repeat the runout procedures until the limits are met.

Exercises (443):

1. Why is it necessary to perform an outer race spacer measurement of the number 4 bearing?

2. What is the purpose of number 3 bearing runout check?

2-4. Reassembly of the Engine Hot Section

Reassembly of the engine hot section is made easier by installing the parts as subassemblies, rather than piece by piece. Manpower permitting, some workers can be putting together a subassembly while others are installing the completed sections of the engine.

444. State how to install the turbine front bearing support, including number 5 bearing and outlet duct assembly.

Turbine Front Bearing Support Installation. The turbine front bearing support is a double-walled unit. Before you install it, apply a thin coating of seal compound to the front and rear flange mating seals of the support. Place a new gasket on the rear flange of the diffuser inner case. Install and tighten the bolts sccessively until all bolts are within recommended torque range. It may require additional torquing before all bolts reach the recommended torque.

Number 5 bearing installation. The number 5 bearing housing is now temporarily secured to the bearing support with several equally spaced bolts. Apply antiseize compound to the number 5 bearing outer race. It is then drifted into the bearing housing with the serial number facing the front of the engine. Install the spanner nut and torque as specified and align rivet holes. The two rivets are installed 180° apart with the heads outward. Next, remove the housing that you temporarily installed and insert the oil pressure tube assembly into the housing next to the spanner nut. Install the oil nozzle and secure with the clamp. There should be no more than 1/32-inch vertical movement.

Outlet duct assembly installation. With the outlet duct assembly hoisted into position, align the screw holes. Install the four flathead screws securing the outlet duct assembly to the turbine front bearing support and tighten to recommended torque.

Exercises (444):

1. What is the procedure for installing the turbine front bearing support?

2. Briefly summarize the procedure for installing the number 5 bearing.

3. To what part is the outlet duct assembly secured?

445. Identify the steps and equipment necessary to perform a position measurement of the front compressor drive turbine rotor.

Axial Position Measurement. To perform an axial position measurement of the front compressor drive turbine rotor, install the loading pusher tool as shown in figure 2-5. Turn the T-handle until 1000 + 50 pounds of pressure is shown on the dial indicator. This removes all the end play from the bearings and gives you an exact reading of clearance between the turbine disc and the turbine nozzle vanes. Use a depth micrometer to take readings at the 3, 6, 9, and 12 o'clock positions. Divide the sum by four to obtain an average of the readings which you compare with the allowable limits. If the measurement is not within the limits, the end shaft spacer will require a replacement. The reading obtained will determine if a larger or smaller spacer is required.

The method discussed is not the only way to make this measurement. There is another way which does not require the turbine wheel to be loaded. No matter what method is used, accuracy is important to insure the efficiency of the turbine.

Exercises (445):

1. What two tools do you need to measure axial position of the front compressor drive turbine rotor using the loaded method?

2. How is an axial position measurement performed using the loaded method?

446. Specify how and where the second-stage turbine nozzle is secured.

Second-Stage Turbine Nozzle Installation. The second-stage turbine nozzle is lifted using a lifting bracket and hoist. Carefully position the second-stage turbine nozzle and spacer in position on the rear face of the first-stage spacer. Align the index marks on the outer diameter of the second-stage nozzle with the marks on the nozzle guide vane assembly and the first-stage spacer. The inner flange of the second-stage turbine nozzle will rest on the outer flange of the turbine outer seal. Remove the safety wire used to temporarily secure the first-stage turbine nozzle outer spacer to the nozzle guide vane assembly. Install the nuts and bolts with the boltheads to the rear and safety wire.

Exercises (446):

1. How is the second-stage turbine nozzle secured?

2. What determines the position of installation on the second-stage turbine nozzle?

447. Tell what bearing is installed on the front compressor drive turbine rotor and where the oil seal carrier sleeve is installed.

Front Compressor Drive Turbine Rotor Installation. The front compressor drive trubine rotor shaft has a tendency to whip during engine operation. Due to the excessive length, the number 4½ bearing was incorporated to eliminate this whip. The outer race is installed in the rear compressor drive turbine rotor shaft. The inner race isinstalled on the outer diameter of the front compressor drive turbine rotor shaft.

The rear of the front compressor drive turbine rotor has a rear hub. On this hub are the number 6 bearing carbon seals

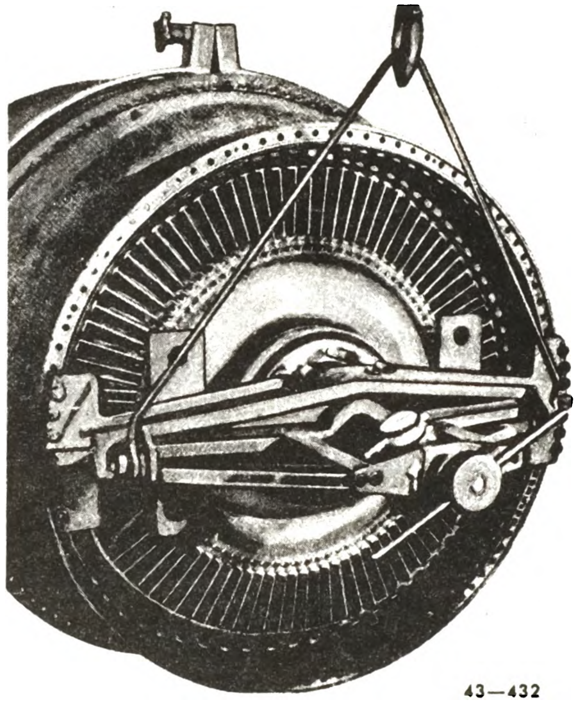

Figure 2 5. Checking axial position of front compressor drive turbine rotor.

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Figure 2–5. Checking axial position of front compressor drive turbine rotor.

and bearing inner race. The number 6 bearing inner race is heated and drifted on the hub. Inside the hub is a threaded surface that receives the oil seal carrier sleeve. Attached to this is the oil suction pump drive pinion. The drive pinion retains the bearing in position in addition to driving the oil suction pump.

Exercises (447):

1. What bearing is installed on the front compressor drive turbine rotor shaft?

2. Where is the oil seal carrier sleeve installed?

448. Name the compound applied to air swirl guides ID and OD of rear segment before installation and the special precaution required for number 4 combustion liner installation.

Combustion Chamber Liner Installation. The combustion chamber liners are subjected to intense heat. To help preclude seizure and aid future removal, apply a thin coating of antiseize compound to the ID of the air swirl guides. Also, apply antiseize compound to the OD of the rear segment of the liners where the support clamp is attached.

During installation be careful to prevent damage to the fuel nozzles, air swirl guides, and the combustion chamber liner crossover tubes. The number 4 liner is the last to be installed and there is an added precaution for it. Guide the combustion chamber air pressure nozzle projecting from the fuel manifold into the air pressure transfer tube in the chamber. Secure each liner and apply the proper torque.

Exercises (448):

1. What compound is applied to each liner before installation?

2. What added precaution is required when installing number 4 combustion chamber liner?

449. Name two things that you must do to prevent "hangup" of the turbine rear bearing and carbon seals, and tell where the oil pressure nozzles are installed.

Turbine Exhaust Case Installation. When you are installing the turbine exhaust case, you must lift it to the correct level to accept the turbine rear hub. You have already packed the number 6 bearing inner race rollers with petrolatum. It must be guided slowly in so damage to the bearing and carbon seals will be minimized. Once the hub is in the case, you should take extreme care that the drive pinion gear engages the number 6 bearing suction pump properly. To do this, you slowly rotate the front compressor drive turbine rotor while exerting some forward force on the turbine exhaust. This will help prevent hangup of the turbine exhaust case. Install bolts and nuts to secure the case and properly torque.

Now visualize what has been accomplished. The number 4½ bearing oil nozzle is protruding into the center opening of the oil tube and shield assembly. The number 6 bearing oil nozzle is placed into the sump weldment port to supply lubrication for the number 6 bearing and the drive pinion gear is engaged with the number 6 bearing suction pump.

Exercises (449):

1. What is done to prevent hang-up when installing the turbine exhaust case?

2. Where are the numbers 4½ and 6 bearing oil nozzles located when the turbine exhaust case is installed?

2-5. Inspection of Engine Parts and Thrust Reverser

There are other components which you will be required to remove, inspect, and reinstall. The items we will cover are the gearbox, QEC parts, and the thrust reverser. We will, also, discuss the rigging of the engine control linkages.

Once you have completed your meticulous inspection and reassembled the engine, you must then insure that the other engine parts will operate properly. If the engine gearbox or some of the parts in the QEC kit should fail, then all of your work will have been done for nothing.

450. Specify why the gearbox is so important to properly inspect and from examples, determine if the drive spline is acceptable and if accessory drive gears may be repaired.

Gearbox Inspection. The engine gearbox must be as thoroughly inspected as the rest of the engine. If there is a severe failure in the gearbox, it could also cause damage to the engine compressor or bearings. The compressor drives the gearbox and the same oil which flows through the gearbox also goes to the engine bearings.

When inspecting the gearbox, you should pay close attention to the oil pressure and scavenge pumps as well as the main oil strainer. Inspect each of the accessory drive gears for damage. Minor damage to teeth may have to be honed out so long as the damage does not exceed a depth of 0.002 inch. Repair of gears must be held to a minimum to avoid excessive backlash and the removal of the case hardening. Backlash of repaired gears must not be increased by more than 0.001 inch.

You must check each of the drive splines for wear. This is done with a special tool which, when properly set, becomes a go-no-go gage. As an example, for a drive with 24 splines, you set the gage to 1.254 + 0.000 to − 0.001 inch. Then you insert the gage at a 45° angle so the balls of the gage will enter at the top and bottom of the drive. Slowly let the gage support itself in the spline. If it will not support itself, the drive is excessively worn and must be replaced.

Exercises (450):

1. What makes the gearbox so important to inspect thoroughly?

2. When inspecting an accessory drive gear, you find a nick which is 0.001-inch deep. Is this gear serviceable? If not, explain what you must do.

3. When inspecting the 24 spline drive, the tool will not support itself when it is set at 1.2541 inch. What should you do?

451. Identify the hazard of using a QEC part from a failed engine and specify reasons to inspect QEC kit parts.

QEC Kit Inspection. Parts that come with the QEC kits can also cause damage to the engine if they are not inspected properly. Parts that have been removed from a failed engine could be contaminated, and this contamination can be passed to a new engine. Make sure that you inspect each part of the QEC kit before you install it on an engine. Air-oil coolers and fuel-oil coolers are very good examples of parts which retain contamination and could cause another engine to fail.

When you install parts such as the hydraulic pump, generator, and constant speed drive, you should check the drive spline to insure they are not worn excessively. You should also check each of the plumbing fittings and electrical connections for security and condition.

All of the tubing, hoses, and electrical wiring must be checked for condition before installation. After these parts are installed, make sure that they are not chafing or putting undue stress on themselves or the item they are attached to. Closely follow the TO to insure the positioning is correct and that all of the supporting clamps are installed.

Exercises (451):

1. What could happen if an oil cooler from one failed engine is installed on another engine?

2. Why would you inspect the hydraulic pump, generator, and constant speed drive before installing them on an engine?

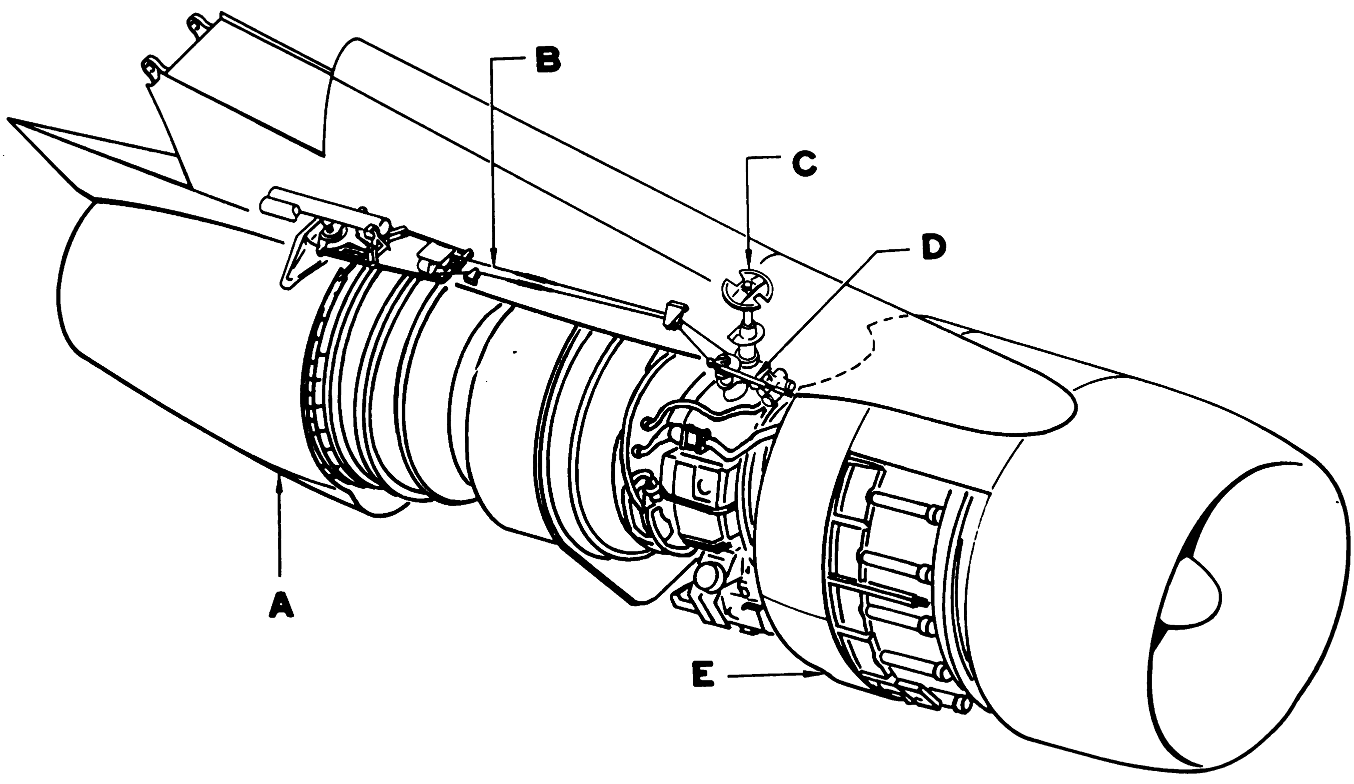
3. What are tubing, hoses, and electrical wiring inspected for after installation?

452. Specify how the thrust reverser affects engine operation and determine whether selected parts of the thrust reverser system must be repaired or replaced.

Up to this point, we have used the J–57 engine in our discussion of the engine disassembly, inspection, and reassembly. For the thrust reverser system, we will switch to the TF–33 which uses a thrust reverser system on some aircraft.

The Thrust Reverser System. While thrust reversers are only used on a few of our cargo aircraft, you must be thoroughly familiar with how it operates. The thrust reverser, shown in figure 2-6, provides an effective means of assisting the aircraft brakes to shorten the distance it takes to stop an aircraft after landing. The thrust reverser system operates independent of the engine operation and does not have any effect on the forward thrust of the engine. The two reversers on each engine operate together during reverse thrust operation. Some aircrafts only use the fan thrust reverser, but we will discuss both the fan and exhaust reversers.

THRUST REVERSER SYSTEM
Description



A. Aft thrust reverser
B. Followup mechanism
C. Control mechanism
D. Followup mechanism
E. Fan thrust reverser

Figure 2–6. Thrust reverser system

Fan thrust reversers. The fan thrust reverser, figure 2-7, has a cowl ring, item D, which moves rearward during reverse operation. Inspect this ring for loose or missing rivets and cracks. Check the technical order for limits, but as an example, if four rivets are missing in a 15-inch row of rivets, then the cowl ring must be repaired or replaced.

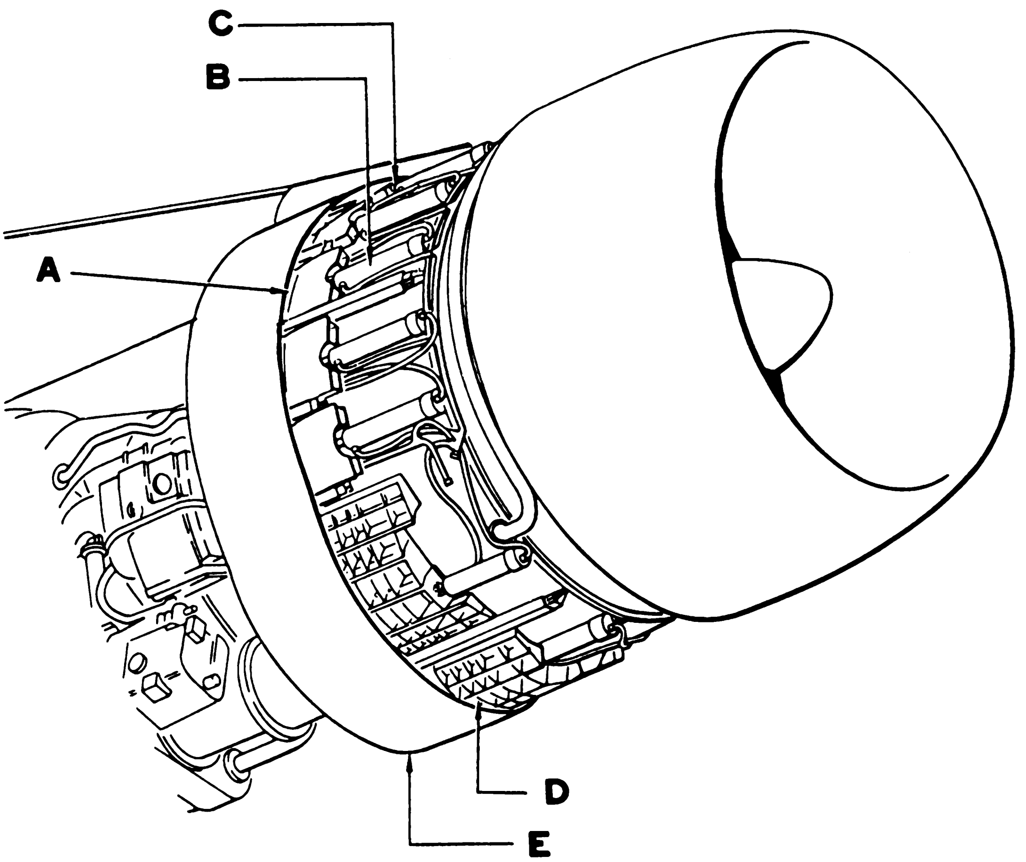
The blocker doors, item A, deflect fan discharge air forward during reverse thrust. As the cowl ring moves rearward, these doors are positioned to deflect the fan thrust forward. The blocker doors are inspected for cracks which may be stop drilled if they are 1 inch or less in length. Small sections of up to 1 inch may be missing from the leading or trailing edge. There can be no cracks in the area of the bearing surfaces.

The vane assembly, item E, is on the lower side of the engine. As the cowl ring moves rearwards, these vanes are positioned to deflect the fan discharge air forward during reverse operation. When replacing these vanes, it is very important to make sure that the proper vane part number is used. If the wrong vane is used, then it is possible that fan discharge air could be directed into the intake of the adjacent engine.

The baffles, item C, are used to direct fan discharge air away from the engine strut during reverse operation. As the cowl ring moves rearward, the baffles move aft into position. When replacing a baffle, the blocker door next to it must be removed first to provide access to mounting bolts.

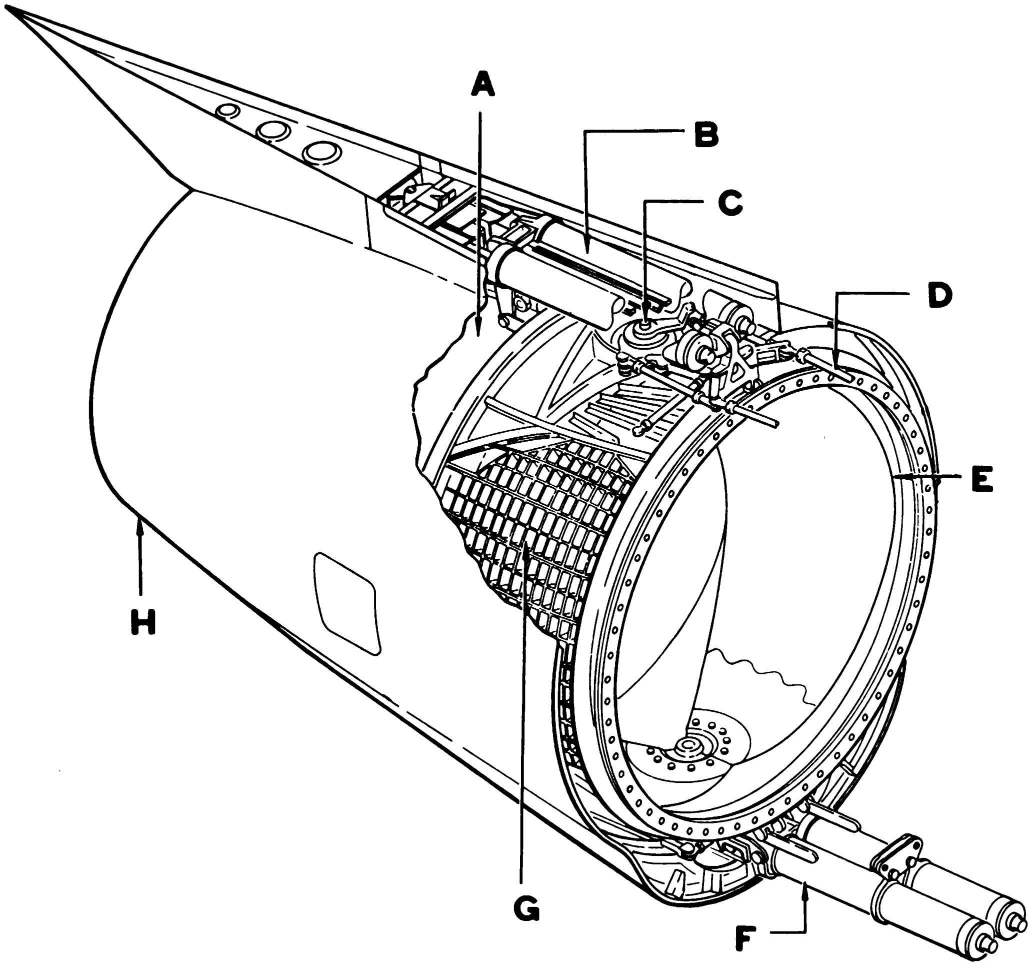
The actuators, item B, are used to position the blocker doors and vane assemblies. The actuators are pneumatically operated by bleed air from the high-pressure compressor.

Aft thrust reversers. The aft thrust reverser, figure 2-8, has a sleeve, item H, which fits over the engine exhaust and aft



A. Blocker doors
B. Actuators
C. Baffles (not shown)
D. Vane assembly
E. Cowl ring

Figure 2–7. Thrust reverser system



A. Exhaust nozzle
B. Upper actuator
C. Clamshell door hinge
D. Followup mechanism
E. Clamshell door
F. Lower actuator
G. Cascade vanes
H. Sleeve

Figure 2–8. Aft thrust reverser

thrust reverser to streamline the engine during forward thrust operation. For reverse thrust operation, the sleeve moves rearward exposing the cascade vanes, item G. When inspecting the sleeve, some cracks are acceptable if they are less than 4 inches long and are stop drilled. Cracks cannot include more than two rivit holes.

Clamshell doors, item E, are inside the aft thrust reverser. During forward thrust, the doors are open and do not interfere with the exhaust gases. For reverse thrust operation, the doors are closed and block off the exhaust nozzle. The exhaust gases are then diverted out through the cascade vanes. Some cracks are also allowed in the clamshell doors if they have been stop drilled and are not beyond length limits. When closed, the doors must not have a gap of more than 5/16 inch.

The cascade vane is an assembly of 10 vanes on the outboard side of outboard engines and inboard side of inboard engines. On the other side of the engines is an assembly of eight vanes and two blockers. This is done to prevent the exhaust gases from one engine being ingested by the adjacent engine. Each of the cascade vanes is a casting of rows of turning vanes at preset angles to deflect the exhaust gases at the most desired angle during reverse thrust operation. No gases pass through the area where the blocker doors are installed. During inspection and repair, only extremely small cracks may be stop drilled on the vanes.

Generally, vanes with cracks over 1/4 to 1/2 inch must be replaced. When replacing cascade vanes, you must make sure the correct part number vane is used. Since the vanes are at predetermined angles for each position on the engine, using a wrong vane will reduce the efficiency of the thrust reverser.

The followup mechanism, item D, connects the fan and aft thrust reverser. It is also connected to the thrust control shaft. The purpose of the followup mechanism is to make sure that the reverser does not move to the reverse position while the engine is at excessive speed. It also does not allow full thrust to be applied until the reversers are in the proper position.

Exercises (452):

1. What affect does the thrust reverser have on the engine operation?

2. Place a check by the following thrust reverser parts that must be replaced.

____ a. The fan reverser cowl ring has four rivets missing in an 18-inch row of rivets.
____ b. One of the blocker doors has a 1½-inch crack.
____ c. The aft thrust reverser sleeve has a 3-inch crack through three rivet holes.
____ d. One of the cascade vanes has two 1/4-inch cracks.

3. What could happen if the wrong part number vane was installed in the fan or aft thrust reverser?

4. What does the thrust reverser followup mechanism do?

GTCP85–180 Engine Disassembly, Inspection, and Reassembly

MOST SMALL GAS turbines are constructed alike, yet each has its own unique characteristics necessary for the unit to perform the specific task for which it was designed. Some units use larger multistage compressors with limited mechanical shaft loading capabilities. Others has little bleed air capabilities, yet are able to provide high-shaft horsepower for operating units like generators and hydraulic pumps. Some engines have four main bearings while others have only two.

There are also small gas turbines capable of high pneumatic bleed, in addition to high-shaft horsepower loading capabilities. In order to give you a wider view of the GTC constructional features, the GTCP85–180, figure 3-1, is the unit referred to in this chapter. This compact ''mightymite'' has high-shaft horsepower and pneumatic bleed loading capabilities and incorporates many features of other gas turbine units. The GTCP85 series is widely used in aerospace ground equipment units and as aircraft auxilary power units. The basic unit requires some modification to permit ease of installation or adaptation of the unit to its primary task in a particular situation.

The GTCP85–180 discussed in this chapter is installed in the M32A–60A ground equipment power unit. It is a self-contained, self-propelled generator set. It provides AC and DC power plus pneumatic power for aircraft use. The GTCP85–180 provides shaft horsepower to drive an AC generator with a transformer rectifer to supply DC power, plus compressed air for starting aircraft engines.

This gas turbine compressor and power unit is made of simple parts which work together to provide proper operation. This chapter presents enough information on the operation and interaction of parts to permit intelligent maintenance of this type of unit.

3-1. Disassembly and Inspection of the Engine

Why is engine disassembly and inspection performed? To answer this question, let us make a comparison. You probably own an automobile. Assuming that your automobile is similar to most others, minor troubles must be corrected to assure proper operation until the car requires complete reconditioning. The same procedure applies to aircraft engines. ''Intermediate maintenance'' is intended to be interim maintenance procedure between overhauls. Intermediate maintenance may also be necessary when an engine develops some deficiency that causes it to vibrate excessively or prevents it from operating at maximum efficiency.

Experience and investigation reveals that most failures of jet engines occur in the ''hot section'' and to some degree in the compressor section. Therefore, intermediate maintenance is performed primarily in these sections.

All values given for inspection in this chapter are chosen for illustrative value only and are not necessarily representative on any engine configuration. For information on a particular engine configuration, consult the applicable maintenance manual.

453. State the purposes of the turbine plenum, identify how the combustion liner is secured at the top and bottom in the turbine section, indicate the faulty component for the condition given in the turbine assembly, and associate turbine section components, with their function.

Turbine Assembly. The turbine power section consists of a cast-type turbine wheel, a turbine plenum, torus, combustion liner, turbine nozzle, turbine shroud, and exhaust pipe. The plenum serves as a receiver for the compressor discharge air, an enclosure for the combustion liner, torus, and a cool encasement of the hot turbine assembly. The torus, mating with the discharge end of the combustion liner, directs the hot combustion gases through the turbine nozzle and shroud assembly. The turbine nozzles are sized, shaped, and positioned so they will efficiently accelerate the high-pressure, high-temperature gases and to direct the gases against the turbine blades at the proper angle. The turbine nozzle is the primary component which limits the flow of compressor air through the turbine, and as such, it is designed to match the requirements of the compressor.

The turbine nozzle, with its shroud, is clamped between the torus and the support assembly. An exhaust pipe screws onto the end of the turbine nozzle and shroud assembly. The forward end of the turbine plenum is bolted to the aft end of the rear compressor housing; its aft end is clamped between the tailpipe and the exhaust flange. The load control valve and plenum drain check valve are attached to the plenum.

Combustion liner. The turbine plenum acts as a housing for the single can-type combustion liner, figure 3-2, item I. The combustion chamber is attached to the combustion cap, figure 3-2, item F, by the fuel atomizer mounting screws. The assembly is then clamped to the plenum so that the discharge end of the combustion chamber slips-fits into the

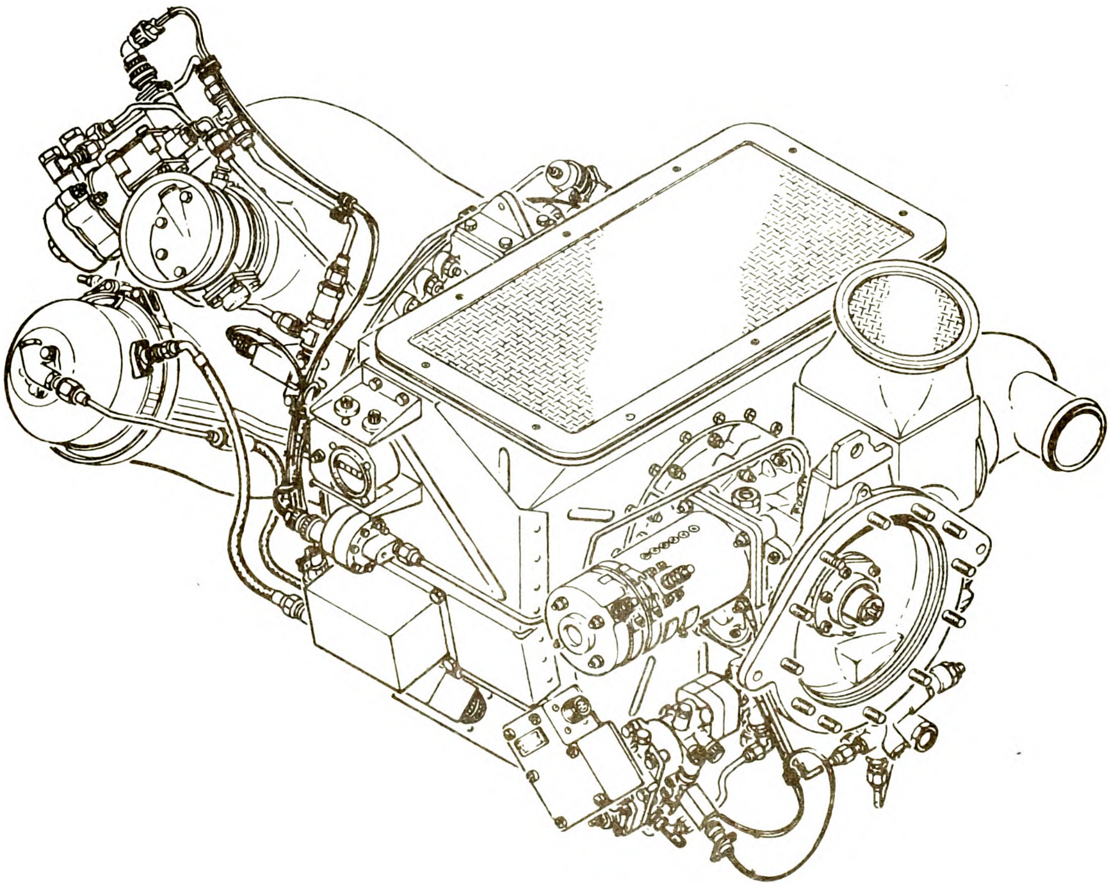
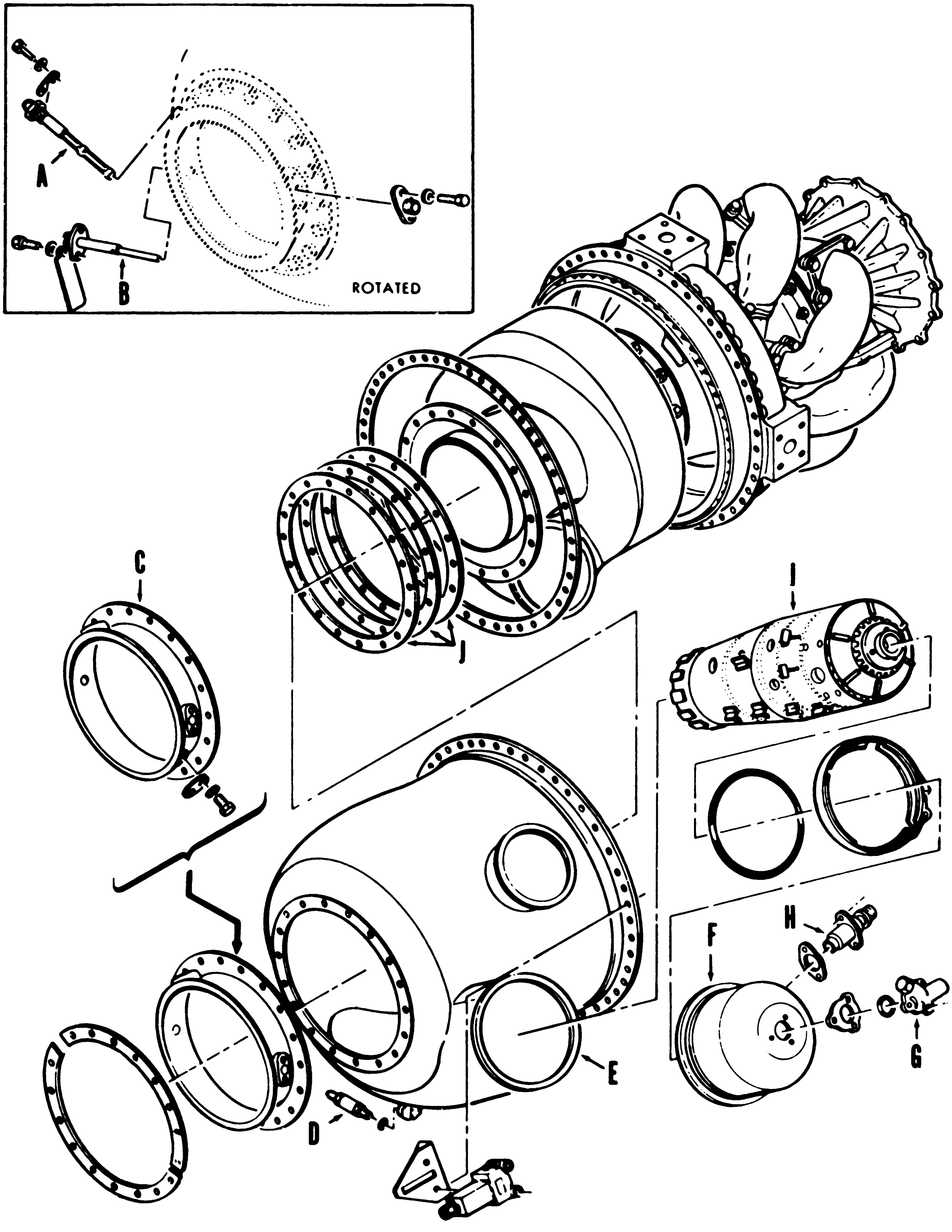


Figure 3–1. Pneumatic and shaft power gas turbine engine.



A. Thermocouple
B. Pneumatic thermostat
C. Turbine flange
D. Drain valve
E. Turbine plenum
F. Combustion cap
G. Dual orifice atomizer
H. Igniter plug
I. Combustion liner
J. Shims

Figure 3–2. Disassembly of the engine.

torus. The combustion chamber forms an air passage between the plenum and torus.

Air enters the combustion chamber through holes of varying diameter as shown in figure 3-2, item I. The holes are sized and spaced to control the quantity of air which flows into the combustion zone. Fuel is injected in the form of a finely atomized spray through a dual orifice atomizer, figure 3-2, item G. The fuel-air mixture is ignited by the igniter plug, figure 3-2, item 137. The section of the combustion chamber within which combustion occurs is referred to as the primary zone. The majority of the combustion airflow is referred to as secondary air, since it is not involved chemically in the combustion process. This secondary air absorbs the heat of combustion, reducing the gas temperature to a level low enough to protect the turbine components. The heat of combustion is adequate to ignite the additional fuel sprayed into the combustion chamber after light off; therefore, continued operation of the igniter is unnecessary as the fuel spray from the atomizer is uninterrupted.

Turbine plenum drain valve. In the event that light off does not occur during a start attempt, fuel which accumulates in the torus will drain through a hole at the lowest point in the torus and flow through the normally open drain valve, figure 3-2, item D, threaded into the bottom of the turbine plenum shown in figure 3-2, item E. The action of the valve precludes booming light offs and flaming starts caused by fuel or oil which may accumulate in the plenum and torus following a malfunction of the engine.

Exercises (453):

1. What are the purposes of the turbine plenum?

2. How is the combustion chamber secured in the turbine assembly?

3. On disassembly of the turbine section, you notice an accumulation of fuel and oil in the turbine plenum. Which turbine section component is faulty?

4. Match the letter corresponding to the component in column B with its function or location in column A. Column B entries may be used more than once.

Column A	*Column B*
____ (1) Screws onto the end of the turbine nozzle and shroud assembly.	a. Turbine plenum.
____ (2) Place where combustion occurs.	b. Exhaust pipe.
____ (3) Receives high velocity gases from the turbine nozzles.	c. Turbine plenum drain valve.
____ (4) Bolts to the aft end of the rear compressor housing.	d. Torus.
____ (5) Drains fuel and oil accumulations from the turbine plenum.	e. Combustion chamber.
____ (6) Directs hot gases from the discharge end of the combustion chamber to the turbine.	f. Turbine nozzles.
____ (7) Increases the velocity of the hot gases directed onto the turbine blades.	g. Fuel atomizer.
____ (8) Sprays a finely atomized fuel mist into the combusion liner.	h. Turbine wheel.
____ (9) Slips fits into the torus.	
____ (10) This component has a drilled hole in its lowest point to drain fuel in the event the engine fails to drain.	
____ (11) This component acts as a receiver of fuel.	

454. List the components to remove before you remove the turbine plenum and, given hypothetical situations, rate the combustion chamber and fuel nozzle for serviceability.

Turbine Section. The turbine section of an engine converts heat energy created by the combustion area into mechanical energy to turn the compressor and accessories. There is a distinct advantage in inspecting parts individually as the engine is being disassembled. Parts, which have to be replaced, are ordered through supply. If they are ordered individually as the engine is being disassembled rather than waiting until the entire engine is disassembled, the parts will start arriving right away. Parts which are not in supply will have time to be shipped in before you need them. This could reduce the chance of having to stop work on the engine because of a lack of parts. Before you disassemble the unit, inspect it for air leakage. This is indicated by dark streaks around clamp couplings or split line areas in the turbine plenum region. Note any hotspots or other type discrepancies at the same time. This brief inspection helps you evaluate the condition of the unit

Turbine Plenum Removal. The entire turbine assembly is housed by the turbine plenum, figure 3-2, item E. To facilitate removal of this plenum, plumbing and electrical wiring must be removed from externally mounted components, such as the differential air pressure regulator and the unloading air shutoff valve. No specific order of removal is recommended; remove items on the basis of accessibility or feasibility. Remove the externally mounted tubing, ducts, and hose assemblies on the turbine plenum by removing the attaching hardware and disconnecting each end from the respective attaching parts. Observe the location and orientation of clamps and other fasteners as an aid in assembling. Remove the thermocouple, figure 3-2, item B, thermostat, item A, from the turbine flange. Exercise caution when storing these delicate components to prevent damage. Then remove the turbine flange, figure 3-2, item C.

Remove and cap the fuel supply line at the fuel atomizer, figure 3-2, item G. Loosen the atomizer mount screws, but do not remove them entirely, because they are threaded into the combustion cap, figure 3-2, item F, to let you remove these three components together. Remove the igniter lead from the igniter plug, figure 3-2, item H. Be sure to ground the igniter lead before you continue maintenance, because the residual current stored in the ignition unit could prove

fatal. The combustion liner and attaching parts may now be removed from the turbine plenum.

At this time, the turbine plenum may be removed by removing the bolts securing the plenum to the diffuser. Remove the bolts starting at the 6 o'clock position and working evenly up both sides removing the top bolt last. This prevents warpage of the flange, as well as binding to prevent damage to other turbine section components. There are several large shims, figure 3-2, item J, placed between the turbine plenum and the pipe assembly. Record the number and thickness of these shims as you remove them. Because of the shape of the plenum, you will need a special storage area to prevent damage.

Combustion liner inspection. Before you inspect the combustion liner, clean the carbon deposits from it. Use a soft material, such as wood, to scrape the combustion liner to prevent damage of the protective coating. Inspect the combustion liner for cracks, buckling, and corrosion or erosion. (NOTE: The limits that follow are for CDC use only.) Always refer to the applicable TO for correct limits. Any crack or buckling greater than the permissible limits is cause for rejection. Inspect the combustion liner as follows:

a. Cracks which connect any two holes are not permissible.

b. Cracks in more than six of the welded joints are not permissible.

c. Reject any deformation of the cylindrical section which is greater than 1/8 inch.

d. Cracks in the cooling skirt are not permissible.

e. Any group of cracks which could cause material to break away is not permissible.

f. Metal thickness must not be less than 0.030 inch because of corrosion or erosion.

g. Cracks longer than 1/4 inch are not acceptable.

Fuel atomizer inspection. Inspect the components of the fuel atomizer as follows:

a. Remove the fuel screen using a screwdriver with a 3/8-inch wide blade or a specially local manufactured tool to prevent rounding out the slot.

b. Inspect all metallic parts for corrosion, wear, nicks, cracks, burrs, and scratches.

c. Inspect all threaded parts for linearity, worn, crossed, stripped or peened threads, and dirt or an obstruction in threads. Make certain that all threaded parts turn freely on their mating parts and do not bind.

d. Inspect orifices in the atomizer plates for burrs or roughness on orifice edges using a 20-power microscope. Any evidence of burrs or roughness of the plates is cause for replacement.

Replace all components of the fuel atomizer which do not meet inspection requirements or are damaged beyond simple repair. Repair minor burrs or roughness with abrasive paper. Do not use sandpaper or other abrasives to clean the fuel atomizer head; alteration of the spray pattern may result.

Exercises (454):

1. What major items, other than hardware, are removed to facilitate removal of the turbine plenum?

2. Using figure 3-3, items A–E, list which of the cracks are acceptable and the ones that would cause rejection of the combustion liner.

3. You are inspecting the fuel atomizer plates using a 20-power microscope and there are burrs on the plates. Abrasive paper is used to remove the burrs. Was this the correct procedure? Explain.

455. Locate where the exhaust pipe assembly is fastened, state how to remove it and the torus assembly.

Torus and Exhaust Pipe Removal. After the turbine plenum is removed, as discussed in the previous objective, the first step is to attach a special wrench to the exhaust pipe assembly, figure 3-4, item A. The exhaust pipe assembly, which has a left-handed thread, is threaded into the aft end of the turbine nozzle and must be turned clockwise for removal. Make sure you always protect the threads on the pipe assembly during storage. Inspect the pipe assembly for damage and material fatigue. Remove the torus assembly, figure 3-4, item B. To do this, you must remove the torus attaching nuts. Then lift the assembly off the engine and store in such a manner as to protect the threads on the studs.

Exercises (455):

1. Where is the exhaust pipe assembly attached?

2. How is the exhaust pipe attached to the engine?

3. What is used to attach the torus to the engine?

456. Specify how to remove the compressor and turbine assembly; name what holds this assembly after removal.

Compressor and Turbine Assembly Removal. Before the compressor and turbine assembly can be removed, you must first remove all of the B–1 accessories on the accessory section. Properly tag and store each item. Then remove the accessory section attaching nuts and washers. You may now remove the accessory section, housing, and gear assembly from the engine. You should tag and store this item to prevent damage.

Now remove the compressor inlet plenum assembly by removing the mounting screws and clamp. Then lift off the plenum assembly; tag and place it in storage.

Remove the turbine shroud and turbine nozzle. Then remove the compressor and turbine assembly and place them in the special holding stand, figure 3-5.

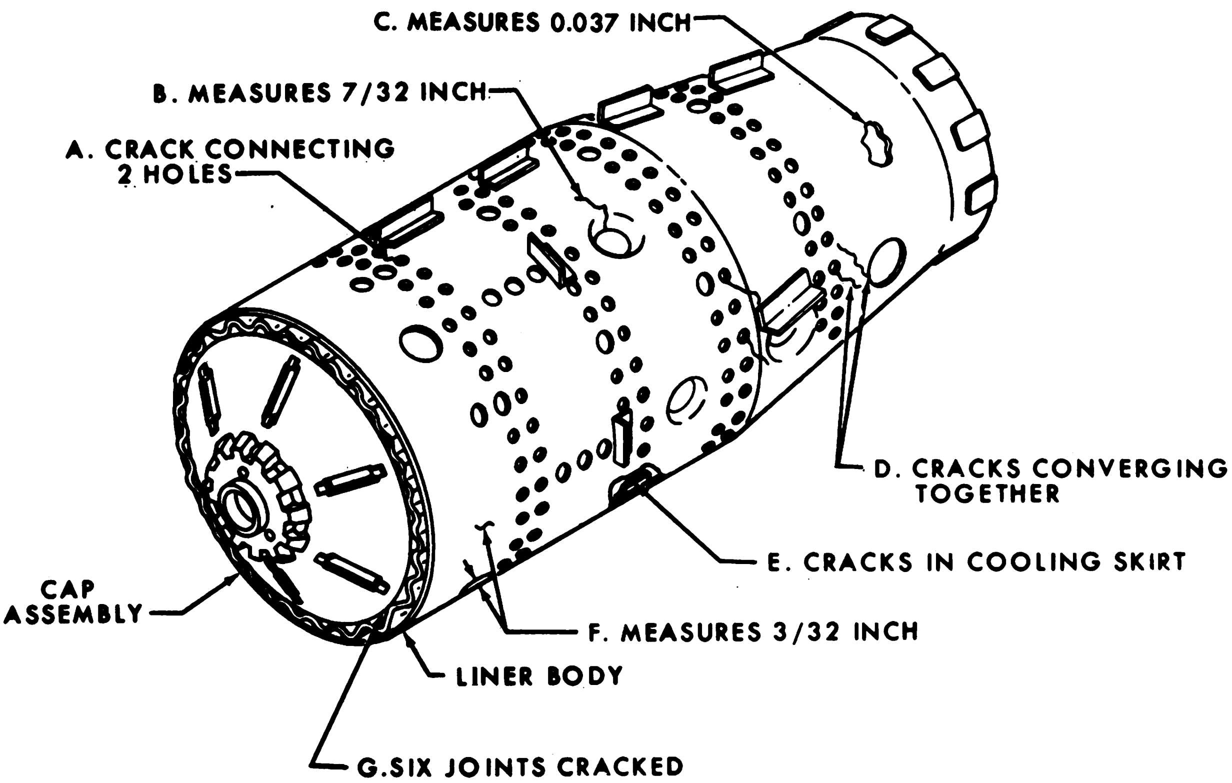
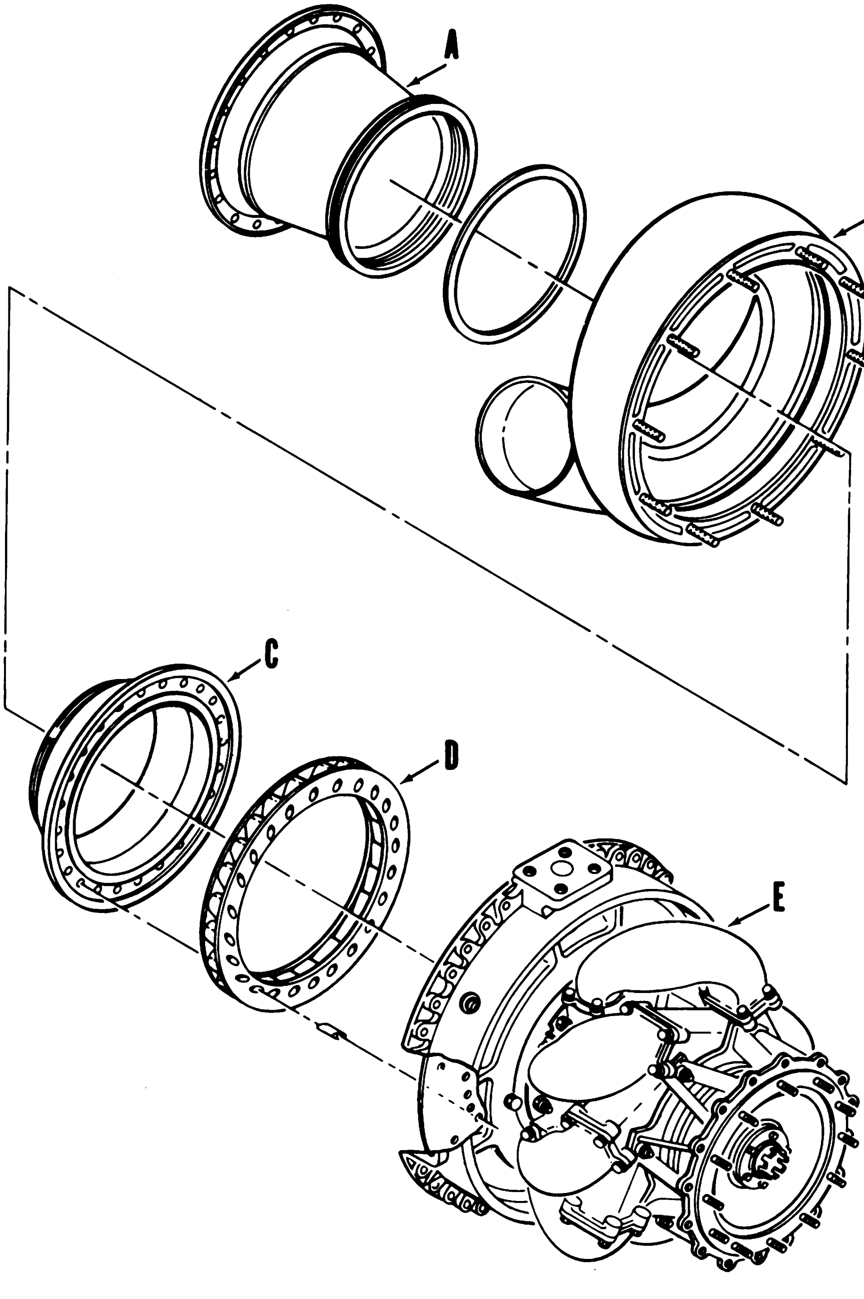


Figure 3-3. Inspection of combustion liner assembly.



A. Exhaust pipe
B. Torus assembly
C. Turbine shroud
D. Turbine nozzle
E. Compressor and turbine assembly

Figure 3–4. Disassembly of torus and exhaust pipe.

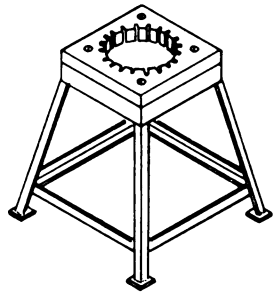


Figure 3–5. Holding stand.

Exercises (456):

1. What items must be removed prior to removing the inlet plenum assembly?

2. What is used to hold the compressor and turbine assembly after removal?

457. Identify how to disassemble the compressor and turbine assembly, state the precaution to use with the curvic coupling, and specify if a turbine wheel or turbine nozzle is within acceptable limits.

Compressor and Turbine Disassembly. The comperssor and turbine assembly requires frequent disassembly for various reasons. As in any gas turbine engine, the turbine section is exposed to extreme operating temperatures. Some reasons for disassembly of the compressor and turbine assembly are FOD, overtemperature, overspeed, seal leakage, and discrepancies noted during the periodic (PE) inspection.

To disassemble the compressor and turbine assembly, you must first straighten the tab lock and remove the nut from the compressor end of the turbine shaft. Next remove the number 1 bearing and retainer. Then remove the inlet housing by removing the attaching nuts. Now remove the impeller retaining nut and, using the proper special tool, remove the housing and first-stage impeller. Make sure that you protect the curvic coupling on the impeller by the use of a plastic cap or similar protective device. This surface is very critical and may be damaged by careless handling. Then remove the second-stage impeller using the proper special puller. The curvic coupling on this impeller must also be protected. Now the number 2 bearing housing and flange is removed, and then the number 2 bearing and carbon seal. The item on the turbine shaft is the bearing spacer. This is removed with a special puller.

Turbine wheel and shaft inspection. Because of the high speed at which the turbine wheel and shaft assembly (fig. 3-6) rotates, if any cracks or rubbing is evident, the turbine wheel and shaft must be replaced. (NOTE: The following list of limits are for CDC use only.) Always refer to the applicable TO for limits when performing actual maintenance. There are several areas to check for wear and damage on this assembly. When inspecting for cracks, use a strong light and a magnifying glass. Cracks will normally extend axially and inwardly from the edge of the turbine blades. The turbine blades must also be checked for stretch and the shaft for wear using micrometers. The splines on the shaft must be inspected for cracks and chipping. Both internal and external splines are checked for wear by measuring with special pins and a micrometer. No repair may be done.

Turbine nozzle inspection. The turbine nozzle must be inspected for evidence of wheel rub. Some small cracks and erosion are acceptable as indicated by the following limits. Refer to figure 3-7 as you read these limits:

a. No cracks are allowed if their continued progression would cause material to breakaway (fig. 3-7,1).

b. Erosion on the leading edge of vane must not exceed 1/16 inch (fig. 3-7,2).

c. Small cracks on the outer edge of the nozzle sideplates which do not exceed 5/8 inch in length are acceptable. No cracks are permitted anywhere else in these sideplates (fig. 3-7,3).

d. There must not be less than 1.00 inch of material between cracks on the leading and trailing edges of four adjacent vanes (fig. 3-7,4).

e. No cracks may extend from the leading to the trailing edge of any two vanes (fig. 3-7,5).

f. Inner vane trailing edge damage from particles striking the vane is normal. Dents in the vanes must not exceed 1/16 inch in depth (fig. 3-7,6).

Exercises (457):

1. What is used to retain the nut on the compressor end of the shaft?

2. Why must the curvic coupling be protected?

3. What must be done if the splines of the turbine shaft has small cracks?

4. When inspecting the turbine nozzle you discover four cracks in the outer edge of the sideplates which are 11/32 inch long. What action should you take?

5. When inspecting the same turbine nozzle you find several small dents on the inner vane trailing edge. What action should be taken?

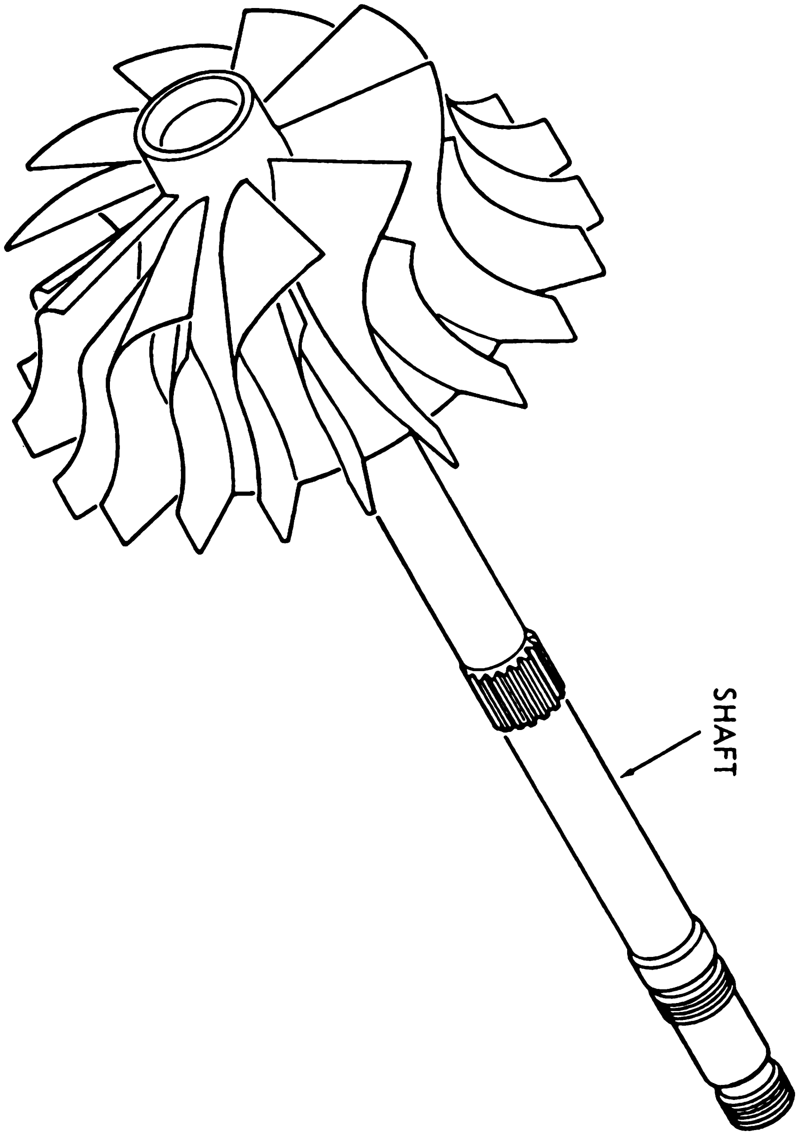


Figure 3–6. Turbine wheel and shaft.

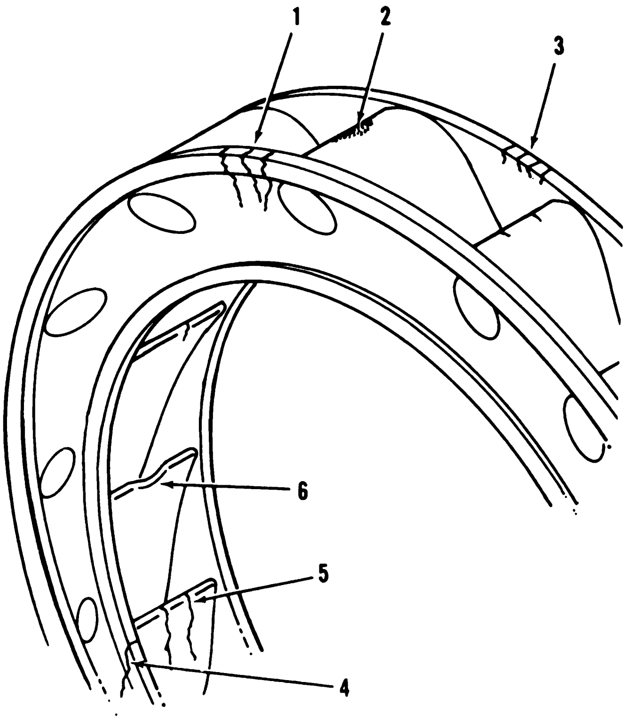


Figure 3–7. Inspection of nozzle assembly.

458. State the purpose of the accessory section, list the components removed from it before its removal, and specify which component drives the sun gear.

Accessory Section. The primary purpose of the accessory section is to reduce the shaft rpm of the unit from approximately 42,000 rpm, to a lower and more usable rpm of approximately 6,000 rpm to drive the unit engine accessories, and provide a mounting place for the accessories. A secondary purpose for the accessory section is to provide a mount and drive pads for customer accessories, such as the AC generators.

Accessory section removal. The accessory gear case and the accessories are illustrated in figures 3-8A and 3-8B. As an assembly, the accessory gear case is bolted to the front and center of the compressor. To remove the accessory gear case, you will first need to remove the following components:

- Centrifugal switch (fig. 3-8A).
- Oil pump assembly (fig. 3-8A).
- Tachometer generator (fig. 3-8A).
- Starter (fig. 3-8B).
- Fuel pump and control unit (fig. 3-8B).

After removing the accessory gear case and housing, the planetary quill shaft (which drives the planetary gears through the sun gear) and the spring are removed.

Planetary gears. The accessory section is driven by a small sun gear connected to the three small planetary gears that reduces shaft rpm. To further reduce rpm, a large ring gear, bolted to the accessory drive output shaft, is installed over the planetary gears. The ring gear, in turn, drives a beveled gear which distributes the power to the accessories.

Oil for lubricating the planetary system is supplied from the accessory drive housing. This oil also lubricates the number 1 bearing and the accessory drive gears.

Exercises (458):

1. What is the purpose of the accessory section?

2. Which five components may form the accessory section before its removal?

3. What drives the sun gear?

459. Name what the number 1 bearing supports, tell how bearings are lubricated, name the components that transfer compressed air from the first to the second stage of compression, and state the percentage of air used to support combustion during pneumatic loading.

Compressor Section. The main components of the compressor section are shown in figure 3-9. This multistage centrifugal-flow compressor is mounted on the front of the turbine shaft. This shaft is supported in the front by the number 1 bearing which is a ball-type bearing. The shaft is supported at the rear by the number 2 bearing which is a journal-type bearing. Both bearings are lubricated by pressure oil and incorporates a dry sump oil system. The number 1 bearing uses a common sump with the accessory assembly.

First stage compressor impeller. The airflow through the compressor originates at the inducer vanes near the center of the first-stage compressor impeller. Air is induced onto the forward and rear faces of the impeller. The air is accelerated by centrifugal force and thrown outward where it is received by divergent ducts. The ducts are curved and port the fast moving air into the inlet of the second stage compressor impeller. The seven ducts, known as interstage ducts, figure 3-9, item J, increase the air pressure by diverting and inducing the high-pressure air onto the forward face of the second-stage impeller. The rear face of the second-stage impeller is blank.

Second-stage compressor impeller. The second-stage impeller repeats the process of the first-stage impeller. As the air leaves the tip of the impeller, it is induced into the diffuser housing, figure 3-9, item G. The diffuser housing is a divergent duct which caused the air pressure to reach its maximum valve. From the diffuser housing the air then enters the turbine plenum. At this point, the airflow is divided with approximately 50 percent of the air continuing into the turbine section for combustion and the remaining 50 percent entering a manifold to be used for pneumatic loading.

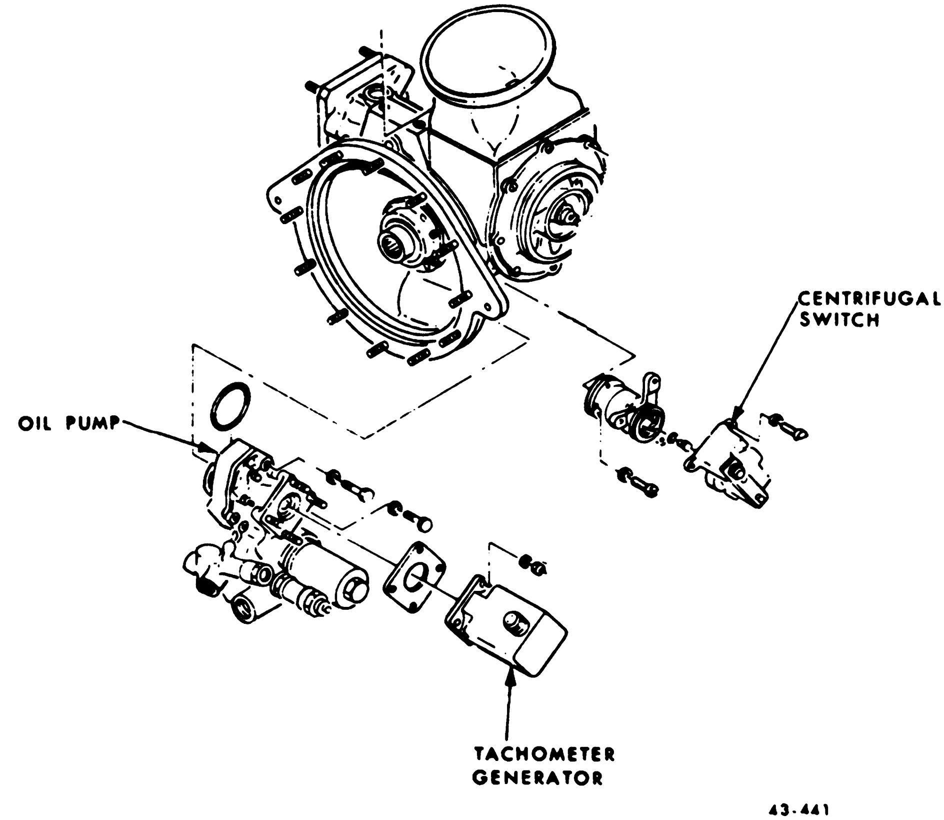


Figure 3–8A. Left front view of accessory section.

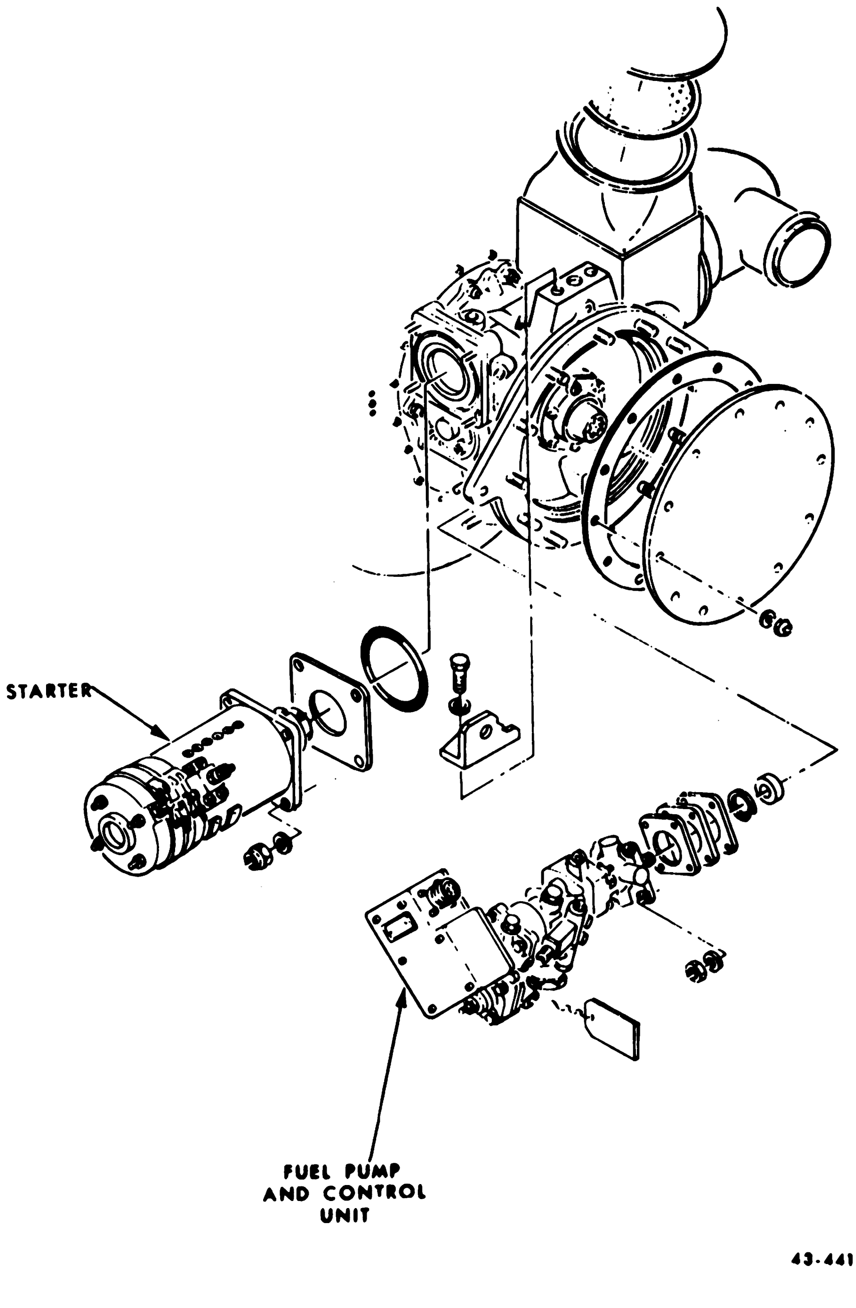
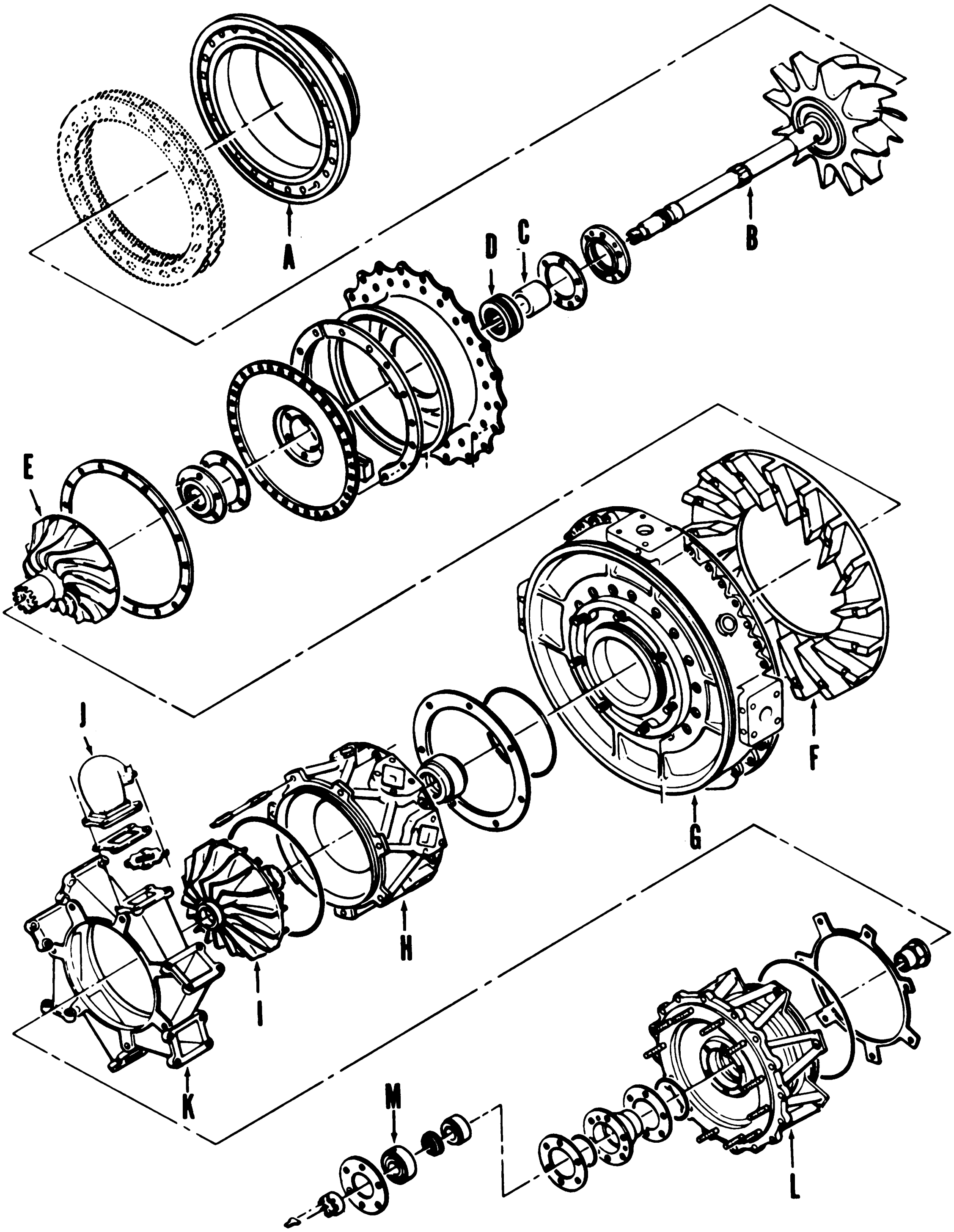


Figure 3–8B. Right front view of accessory section.



A. Turbine shroud
B. Turbine and shaft assembly
C. #2 bearing spacer
D. #2 bearing
E. 2nd stop compressor
F. Diffuser
G. Diffuser housing
H. Compressor housing
I. 1st stage compressor
J. Interstage duct
K. Diffuser assembly
L. Inlet housing
M. #1 bearing

Figure 3–9. Compressor section.

Exercises (459):

1. What does the number 1 bearing support?

2. How are the bearings lubricated?

3. What transfers compressed air from the first-stage impeller to the second-stage impeller?

4. What percentage of air is used to support combustion during pneumatic loading?

460. Using figure 3-9, locate the number 1 and 2 bearings and specify action to take if a compressor is found to be out of inspection limits.

Compressor Section Disassembly. To detect possible damage of the compressor section, you must disassemble the compressor, as illustrated in figure 3-9. Once you remove the compressor plenum and diffuser, you then remove the bolts, nuts, and washers to facilitate the removal of the compressor subassemblies. You should follow the step-by-step procedure we discussed in behavorial objective 456.

Compressor Assembly Inspection. After you disassemble and clean the compressor section, inspect it to locate all damage and defects that may exist. Inspect each part for burrs, nicks, dents, roughness, stripped threads, fine cracks, bad alignment, and metal fatigue. You should take care to notice even the slightest damage, since the engine cannot operate with precision and at maximum performance if these defects exist. If you find any of the parts damaged beyond allowable service limits, repair or replace them according to TO specifications.

Extensive repairs, such as compressor replacement and major overhaul, can be performed at the intermediate level. Repair of the compressor itself must be performed at depot.

When making an inspection, you can examine many of the compressor parts visually for defects. Other parts require you to use micrometers and other measuring instruments and gages. More deep-seated damage can be detected by more extensive inspections. Nondestructive inspection specialists can perform these inspections.

When you repair parts, make the repairs as prescribed in the proper TO. When parts are to be replaced, take great, great care to see that the correct replacement parts are used.

Exercises (460):

1. Using figure 3-9, find where number 1 and 2 bearings are located?

2. What action should be taken if you find the compressor to be out of the prescribed TO limits?

3-2. Engine Reassembly

After all inspection and repair work has been completed and the necessary replacement parts and new seals and gaskets have been obtained, the engine may be assembled. It is obviously impractical to include a job plan for assembling the engine, because the procedure is essentially the reverse order of disassembly. There are several important tolerances, clearances, and checks that must be considered during the assembly procedure. Regardless of the reason, your main duty as a 7-level technician is to insure that specific checks and measurements (along with other maintenance procedures which are discussed in this section) are properly performed.

461. Name the TO that provides the limits for specified checks during engine assembly, determine if compressor concentricity is acceptable, specify why the turbine wheel to shroud clearance check is performed, why the amount of travel required during this check is needed, and what must be done if the first stage impeller travel is incorrect.

Specific Checks and Measurements for the Compressor and Turbine Assembly. There are many measurements that you have to make during engine reassembly. Replacing certain parts requires you to take measurements. Sometimes shims or spacers must be added or removed to bring the fit within specified TO limits. The exact limits for these specific checks are outlined in the jet engine intermediate maintenance TO. The following checks were selected, out of the several used, to acquaint you with the procedures for performing specific checks and measurements. They are the compressor concentricity check, the turbine wheel to turbine should clearance, and the first-stage impeller travel measurement.

Compressor concentricity check. This check is made to insure that the concentricity of the first- and second-stage impellers is within limit. To perform this check you first assemble the turbine, spacer, first- and second-stage impeller (aligning arrows on the curvic coupling 180° apart), and install the impeller retaining nut. Stretch the shaft to within specified limits and install the assembly in the concentricity checking holder, as illustrated in figure 3-10. Then position the dial indicator so the runout probe is against the first-stage impeller shaft near the curvic coupling. Rotate the assembly by hand and watch the dial indicator. The runout must not exceed 0.001-inch total indicator reading. Now move the dial indicator and probe to the second-stage impeller shaft near the curvic coupling and perform the check again. If either reading exceeds 0.001-inch total indicator reading, then disassemble the parts and rotate the spacer or the impellers 120°. Reassemble the parts following the previous procedures and perform the concentricity check again. You should strive to obtain 0.0005 inch during the check to insure that the shaft runout will not exceed 0.001

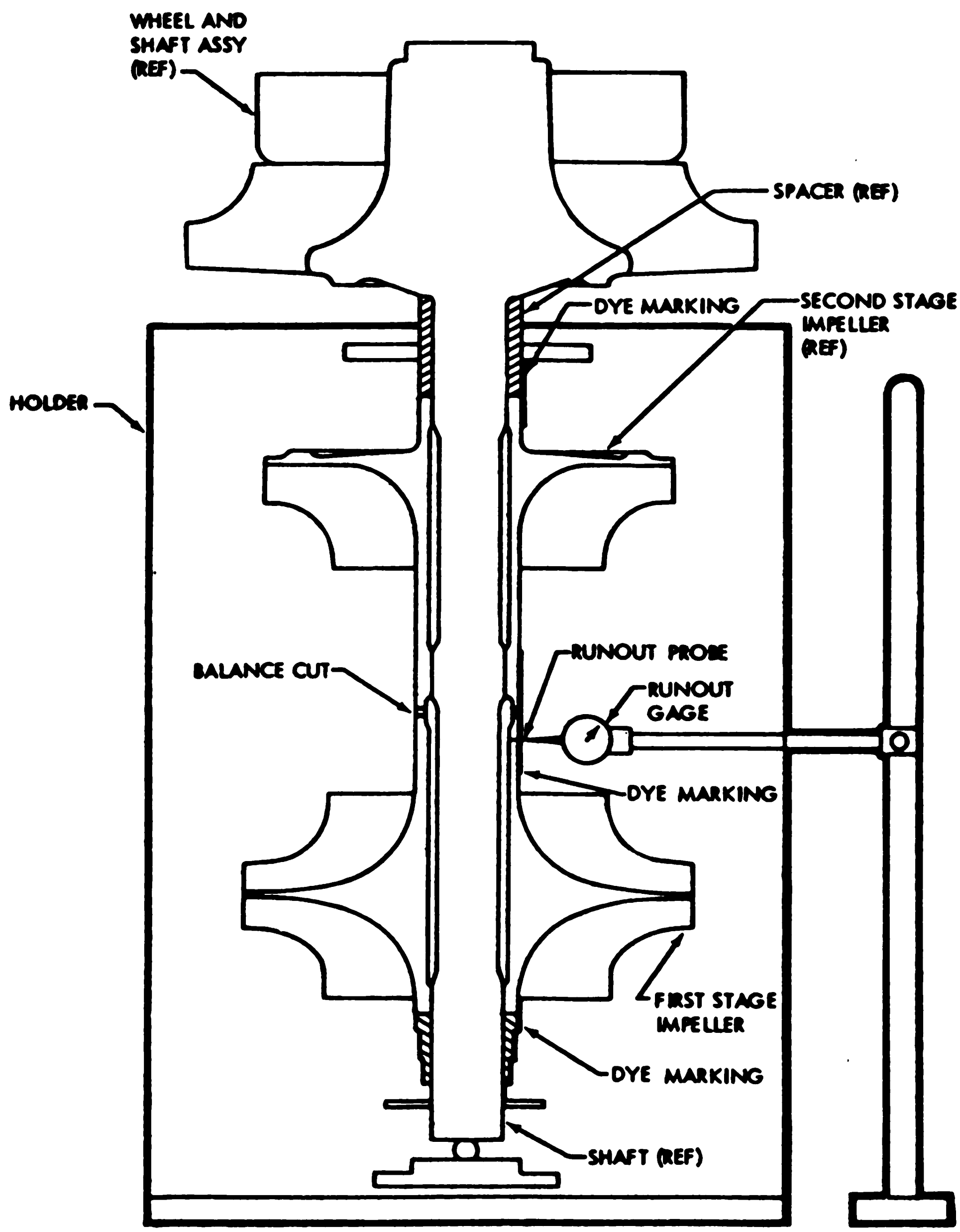


Figure 3–10. Compressor concentricity check.

inch when the assembly is installed. Once you have a proper reading, mark a straight line with dykem on all of the rotating parts. This insures that when the engine is assembled each of these parts will be in exactly the same relative position.

Turbine wheel to turbine shroud clearance. This check is done to insure proper clearance between the turbine wheel and the turbine shroud. If this clearance is too small, there could be rubbing during operation.

To perform this check, first assemble the exhaust pipe, turbine shroud, nozzle, and the turbine shaft with spacer aligned with dykem mark. Install the shroud assembly on top of the turbine nozzle with four bolts placed 90° apart. Install the diffuser housing assembly with four bolts 90° apart. Torque to proper torque value in pairs 180° part. Next install the compressor housing assembly and inlet assembly using four nuts 90° apart. Now you are ready to install the dummy carrier and bearing and the checking fixture shown in figure 3-11. Press down on camshaft handle while rotating turbine shaft assembly. This action lifts up the turbine shaft assembly and indicates on dial indicator the total travel. This reading must be a minimum of 0.078 inch. This amount of travel is required to insure that there is enough room to properly stack the rest of the engine.

First stage impeller travel measurement. This measurement is accomplished to properly position the front face of the first stage impeller in relationship to the inlet housing. For this measurement, use the TO to assemble the engine up to the installation of the inlet housing.

This measurement is started by using a trail shim thickness of 0.027 inch. Install this amount of shims and the inlet housing with four nuts and torque. Press down on the checking fixture camshaft handle, figure 3-12, and measure the total travel on the dial indicator. The total travel shall be 0.022 to 0.024 inch. If total travel is not within limits, then adjust the shims to obtain the required measurement. If this measurement is not done accurately, damage to the engine could result.

Exercises (461):

1. Where can you find the limits for specific checks during assembly?

2. During a compressor concentricity check the runout reading is 0.0008 inch. Is this acceptable runout?

3. What should you do if the runout is unacceptable during a compressor concentricity check?

4. What could be the cause of a turbine wheel rubbing the shroud?

5. If total travel of the turbine shaft is insufficient during the turbine wheel to shroud clearance check, what could result?

6. When performing the first-stage impeller travel measurement, you have a reading of 0.028 inch. What should you do?

462. Specify the corrective action to take when a castellated nut cannot be tightened within the prescribed minimum and maximum torque ranges, use the formula to get the proper correction factor for the torque handle setting in a given situation.

Torquing. During engine assembly, bolts and nuts require a definite amount of torque. Torque values are found in the Table of Non-Standard Torque Values for this particular engine. We must use the applicable torque wrenches for tightening bolts, nuts, and threaded fittings. Be sure the torque wrenches are calibrated periodically to assure their accuracy.

When you tighten nuts or bolts to the correct value, be sure mating parts are properly seated. The preferred practice of torquing is to run the bolts or nuts down until the parts are firmly seated, using a staggered sequence if there are more than three nuts or bolts involved. When all bolts or nuts are exerting sufficient tension to properly seat the part, loosen one nut or bolt at a time and apply the final torque. A staggered sequence of final tightening is preferred in most instances. When the minimum and maximum torque values are given for castellated nuts or nuts with tab lock washers, torque the nuts to the minimum value listed, and then tighten them to the next locking position without exceeding the maximum torque limit. If the nut cannot be tightened within the torque range, replace the bolt, nut, or washer.

When a torquing application is such that an extension is required with the centerline of the extension intersecting the extended centerline of the torque handle frame (fig. 3-13), the correct setting for the torque handle may be determined by the following mathematical formula:

S = handle setting
T = torque applied at the end of adapter
La = length of handle in inches
Ea = length of extension in inches

$$\frac{T \times La}{(La + Ea)}$$

For example, if you wish to exert 100 inch-pounds at the end of the extension, when La equals 12 inches and Ea equals 6 inches, you can determine the handle setting by making the following calculation:

$$S = \frac{100 \times 12}{(12 + 6)}$$

$$S = \frac{1200}{18}$$

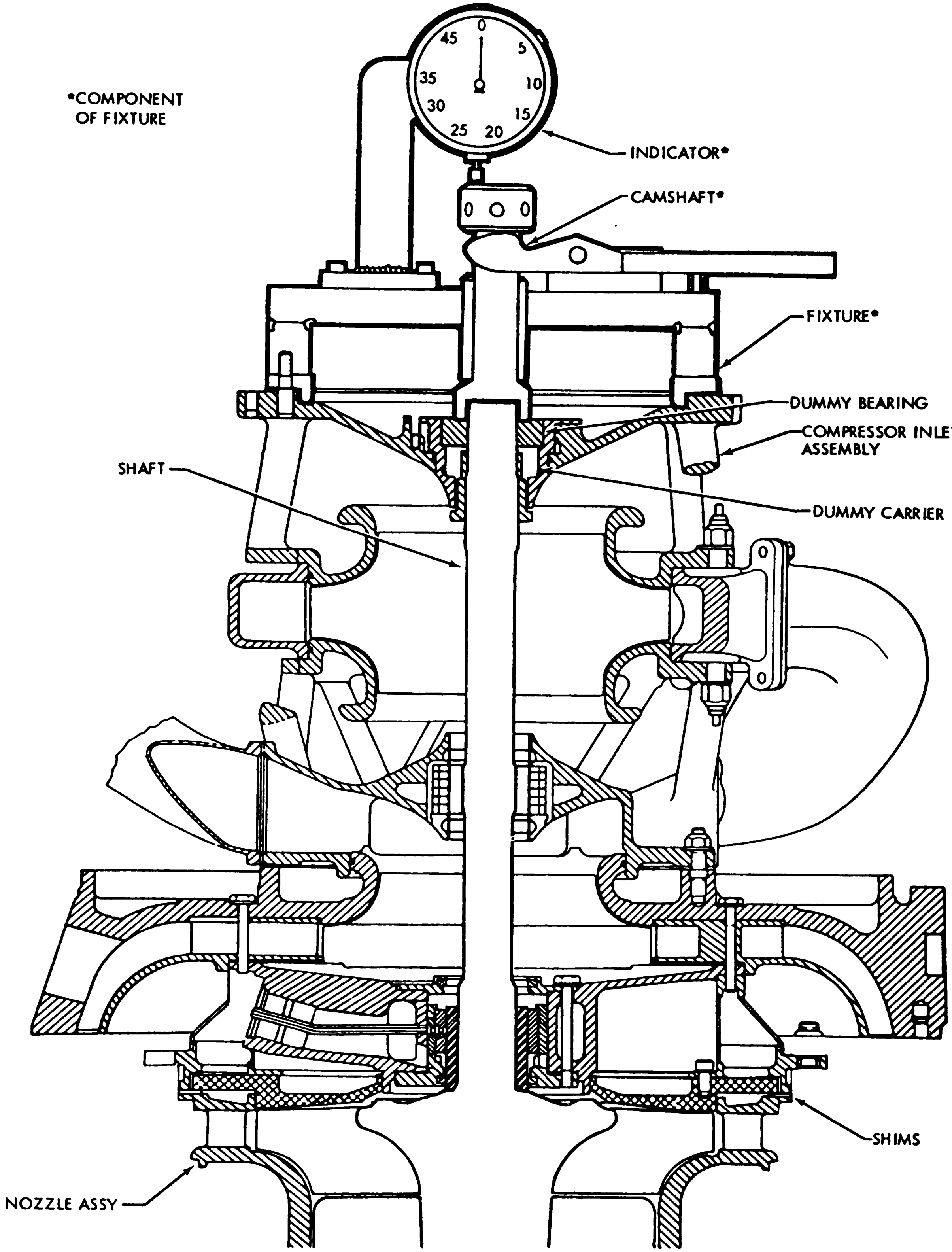


Figure 3–11. Turbine shroud clearance check.

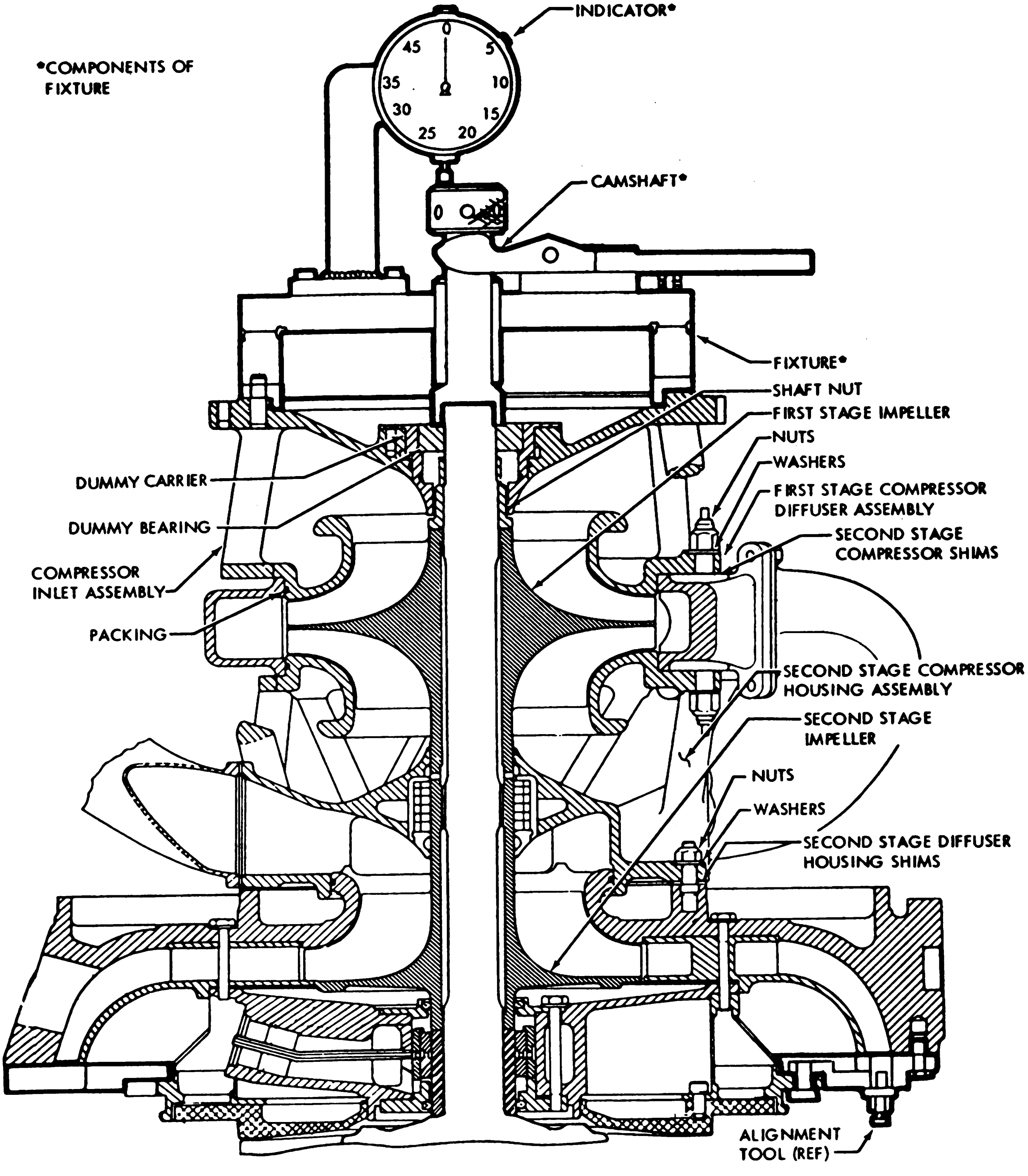


Figure 3–12. First-stage inpellar travel measurement.

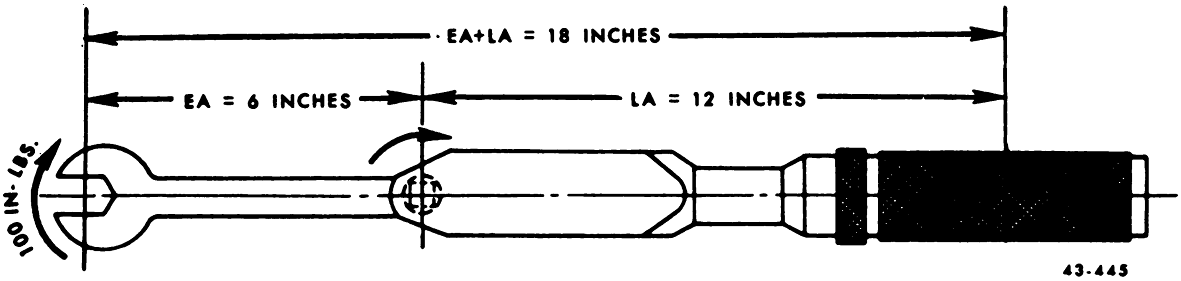


Figure 3–13. Torque wrench with an extension.

The length of the extension, as shown in figure 3-13, is the distance between the center of the square drive and the center of the broached opening. The length of the handle must always be the distance between the center of the square drive and the center of the handgrip.

Exercises (462):

1. You are torquing a castellated nut. The minimum torque value is 50 inch-pounds and the maximum torque value is 60 inch-pounds. The slot in the castellated nut cannot be aligned with the locking hole in the bolt. What corrective action should you take?

2. In the following situation, use the given information to conclude the desired torque with the information provided. You wish to exert 200 inch-pounds at the end of an extension, the length of the handle is 12 inches and the extension is 8 inches. What should the desired torque handle setting be?

463. Identify the clock positions of the boltholes when safetying two units together, specify which direction the safety wire is twisted between boltholes for two and three units, and state the amount of twist left on a braid when cutting off the excess amount.

Safety Wiring. Another very important step is safety wiring. Check the units to be safety wired to make sure that they have been properly torgued and that the wiring holes are properly positioned in relation to each other. When there are two units, the hole in the first unit should be between the 3 and 6 o'clock position. The second unit should be between the 9 and 12 o'clock position. Positioning the holes in this manner insures that the wiring will have a positive locking effect on the two units, since the braid will always exert a tightening pull on both units. Never overtorque or loosen the units to obtain proper alignment of the holes; if you cannot obtain a proper alignment of the holes without either overtorquing or undertorquing, select another unit. The following paragraphs detail a step-by-step procedure for proper safety wiring.

Insert the wire of the proper gage through the hole which lies between the 3 and 6 o'clock position on the bolthead. Grasp the left end of the wire with the fingers and bend it clockwise around the head of the bolt and under the other end of the wire. Pull the loop very tight all around the head of the bolt with pliers. Grasp the wire only at the end to prevent mutilating any portion which is to be twisted. By holding the wire ends apart and keeping the loop tight around the head of the first bolt, twist the wires around each other in a clockwise direction to form a braid. Continue twisting the wires by hand toward the second bolt until the end of the braid is just short of the hole in the second bolt which lies between the 9 and 12 o'clock position. Make sure that the loop around the first bolt is still tight and in place; then grasp the wires in the jaws of the pliers just beyond the end of the braid and, with the braid held taut, twist in a clockwise direction until the braid is stiff.

Twisting the braid in a clockwise direction has the effect of securing the loop down around the head of the bolt. The rigidity of the stiff braid reduces vibration and resultant wear. Do not overstress the wiring by attempting to twist the braid too tightly.

After making sure that the braid is not so long that it cannot be pulled taut between the bolts, insert the end of the wire that is on top at the end of the braid through the hole between the 9 and the 12 o'clock positions on the second bolt head. Grasp the end of the wire with the pliers and pull the braid taut. Bring the other end of the wire counterclockwise around the head of the second bolthole. Pull the resulting loop tight with pliers; then twist the wire ends together in a counterclockwise direction. Twisting the wire ends in a counterclockwise direction will keep the wire in place down around the head of the second bolt. Grasp the ends of the wire beyond the twist with the pliers and, keeping the wires under tension, twist them tight in a counterclockwise direction. With the final twisting motion of the pliers, bend the twisted wire ends in around the head of the second bolt to the right. Cut off the excess wire at the ends with diagonal cutters, leaving at least three full twists. Avoid sharp or projecting ends. Do not twist off the ends of the wires with pliers.

Examples 1 through 5 on figure 3-14 illustrate the proper method of wiring bolts, fillister head screws, square head

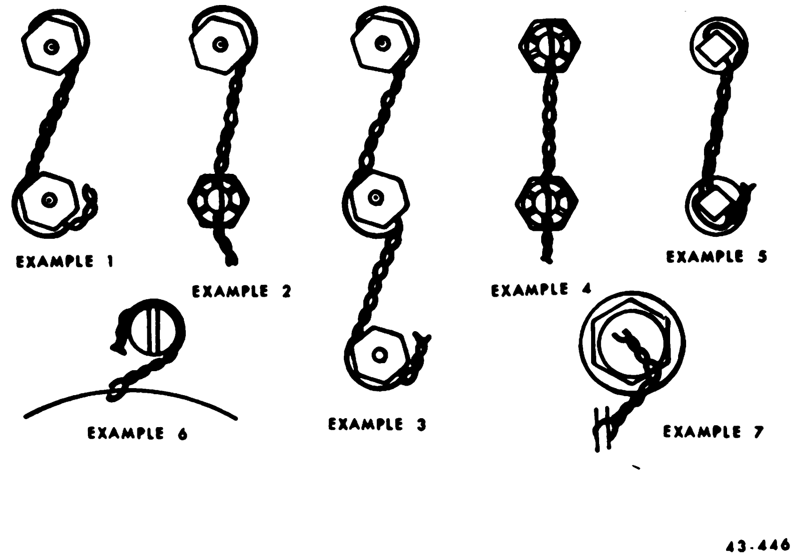


Figure 3–14. Examples of safety wiring.

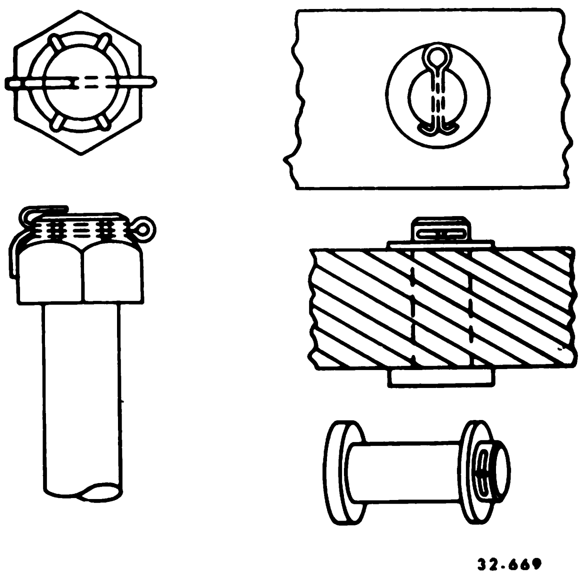


Figure 3–15. Use of cotter pins.

plugs, and similar parts that are wired diagonally in pairs. Example 2 is the method of safetying a bolt to a castellated nut. Example 3 shows how to wire three or more units together diagonally. Twist the braid ends between the second and third units counterclockwise so that the wire from the hole in the second unit will be on top of the loop around the second unit to hold it down in place. The wire inserted into the lock wire hole in the third unit should be the lower wire of the braid and beyond the third unit, bring this wire over the other to secure the loop in place. Example 4 illustrates the proper method of lock wiring studs and castellated nut together. Examples 6 and 7 show the way to wire a screw or plug to a fixed point, such as a lug on a boss.

Exercises (463):

1. When safety wiring two bolts together, in what position should the safety wire holes be located?

2. When safety wiring two units, in which direction should the safety wire be twisted?

3. When safety wiring more than two bolts, in which direction is the safety wire twisted between the second and the third hole?

4. How many twists should be left on the braid when cutting the excess amount off?

464. Identify the two primary precautions for safetying a unit with cotter pins and tell how checknuts and lockwashers secure components.

Securing Devices. The following securing devices you will use require mechanical skill and a knowledge of aircraft hardware.

Cotter pin. The cotter pin is shown in figure 3-1. It is used for safetying various units such as castellated nuts, clevis pins, and flathead pins. As an example, a 1/4-inch diameter bolt is drilled to receive a cotter pin 1/16 inch in diameter. Any installation requiring a safety pin smaller than 1/16 inch in diameter will use 0.041-inch steel wire. The cotter pin should be installed as illustrated in figure 3-15. To remove the cotter pin, straighten its prongs and then remove it with a cotter pin extractor or diagonal pliers. A cotter pin should never be reused.

Checknut. The checknut gains its safety factor by the friction between metals. Tighten down the checknut after tightening the plain nut to the specified torque. Hold the plain nut with another wrench to prevent it from turning while you tighten the checknut.

Lockwasher. A lockwasher maintanins its safety factor by exerting spring pressure on a nut or screw. Because the threads of the screw or bolt are kept under tension, they resist any tendency of the bolt or screw to turn.

Exercises (464):

1. In addition to using the correct size, what other rule should you always observe when you safety a unit with cotter pins?

2. How do checknuts and lockwashers secure components?

Block Testing and Equipment

YOU NEED A MEANS of determining the condition of a repaired or overhauled engine. The quality of work your mechanics produce will have a direct effect on engine reliability and your shop workload. Block testing of engines is your best measuring device for all these items. During a block test, performance such as thrust, exhaust gas temperature, fuel and oil consumption, engine pressure ratios, and other data are carefully observed and recorded on the applicable logsheet.

This portion of the text is to familiarize you with the A/M37T–20 jet engine test stand and its associated test equipment. You must understand the use and purpose of this equipment in the performance of your duties as a jet engine technician.

4-1. Block Test Procedures

The test cell operator must fully understand the importance of performing the tests with which he or she is charged. Such tests are as vital as any other phase of intermediate maintenance. Early failure of the engine can be the result of the test cell operator's carelessness or ignorance. Many instances have occurred in which engines that were in perfect mechanical condition before the test proved to be unsatisfactory after testing. Improper procedures can result in compressor rotor or startor blade damage, overtemperature, overspeed, vibration, damaged bearings, and unreliable performance. In addition to the installation of jet engines in the appropriate test stand, the test cell operator is responsible for calibration of test facility instruments, performance test runs, and engine adjustments. The block test facilities are equipped with more elaborate instruments and measuring devices than are the aircraft. Thus, specific engine operating variables can be accurately measured to determine the reliability of the powerplant.

Technical orders contain the generalized instructions for the operation of a block test facility. These technical orders cover the test facility instrumentation and service systems, the general test procedures, the use of performance correction charts, and the procedures for the calibration of the test facility. Specific information on a particular test facility can be found in the applicable 33D4 series TOs.

465. State the purpose of and identify the different types of engine test requirements.

An engine is block tested for several reasons which can be grouped into two main categories: to check the quality of the maintenance which has been performed, and to determine if the engine and its associated parts are servicable. Standard engine test procedures have been developed which will test an engine in these categories. These tests are discussed next.

Types of Tests. The test cell operator must become familiar with test run requirements and instructions for computing engine performance as outlined in applicable TOs. The type of test to be given a reworked engine depends on the maintenance performed, the particular section of the engine which was reworked, and in some cases, the type of test cell or equipment available to operationally check the engine. Test numbers 1, 2, and 3 provide for complete functional and operational tests of current USAF jet engines with thrust rating up to 35,000 pounds.

Test number 1. This test is for engines requiring minimum operation and thrust and trim checks. The test also includes the trim procedure if the previous checks indicate that a trim is necessary.

Test number 2. This test is necessary for a functional acceptance test after major repair or after parts replacement. Test number 2 may become necessary as a result of discrepancies or difficulties encountered during test numbers.

Test Number 3. Test number 3 is for engines removed for scheduled maintenance. This test run is used to determine engine condition prior to performance of maintenance and will also serve as an aid in determining the degree of maintenance required.

Exercises (465):

1. Why is it necessary to test the performance of a jet engine?

2. Specify what comprises test number 1.

3. What additional performance is measured in test number 2?

4. What is the purpose of test number 3?

466. State the advantages of block testing an engine with the QEC kit installed and list three objectives completed on the test stand following maintenance or engine buildup.

Testing with QEC Kit Installed. Block testing an engine with the QEC kit installed can save many work hours needed for other efficient shop operations. QEC kit testing permits both premaintenance analysis and postmaintenance adjustments without extensive aircraft downtime. Engines removed for maintenance may be installed and operated in a test stand without having to remove the QEC kit. Most systems can be analyzed as if the engine were installed on the aircraft.

After the completion of either engine maintenance or buildup, the following objectives may be performed on the test stand:

a. Systems and units making up the complete power package may be tested to the degree necessary to assure trouble-free operation until the next scheduled periodic inspection.

b. Preliminary engine trim adjustments can be made, thereby eliminating excessive operation after the engine is installed on the aircraft.

c. Maintenance operations such as field cleaning and exhaust gas temperature (EGT) spread check may be performed.

Exercises (466):

1. What benefits can be derived from block testing an engine with the QEC kit installed?

2. Following engine maintenance or buildup, what are the three objectives that may be performed with the engine installed in the test stand?

4-2. Portable Test Facility

You now have a general idea about engine testing and operation. You should become acquainted with a portable test facility which was designed for engines having thrust ratings up to 35,000 pounds. All portable test facilities are basically the same in construction and operation. The A/M37T–20 test facility is representative of the 35,000 pound class.

467. Associate the major items of test cell equipment to the corresponding aspect of their identification.

Major Units. The test stand, figure 4-1, consists of the following major units: control trailer, engine thrust trailer, fuel tank trailer, an optional hydraulic trailer, and a miscellaneous equipment kit.

Control trailer. The control trailer, figure 4-2, is a basic four-wheel trailer, item G, with a structural chassis for mounting the control cab, item B, air-conditioner duct, item C, and support frame. It is equipped with a steerable front axle, item F, with a tow bar. The rear axle has a parking brake, item A. There are four adjustable support jacks to stabilize the trailer during use.

Engine thrust trailer. The engine thrust trailer, figure 4-3, consists of a 10,000-pound capacity engine transport trailer and an engine thrust frame of special design. The basic four-wheel trailer assembly has a steerable front axle and an extendible tow bar. The rails are compatible with standard Air Force rail transfer equipment. The height of the rails is adjustable up to 40 inches and has a thrust frame added for engine support during testing. The thrust frame consists of two parallel upper rails that are interconnected by cradle-type support yokes at each end. The thrust frame is supported from the basic trailer by four tension-type flexure plates. Two 25,000-pound strain gage load cells for measurement of engine thrust up to 35,000 pounds are mounted on the rear support yoke of the thrust frame. The engine thrust is transmitted from the thrust frame to the load cells. Provisions for attachment of the thrust restraining linkage during engine operation and the thrust calibration fixture during calibration are also provided by the flexure plate mounting blocks.

Leveling jacks. Leveling jacks, figure 4-3, are mounted on each corner of the engine thrust trailer to provide for removal of the wheel and tire assemblies. They provide an adjustment for rail compatibility with engine transportation trailers and a means of leveling the engine being tested. They also support the engine thrust trailer at a height of 40 inches during tests. The rails are standard for Air Force equipment transfer capability. Upper rails are locked to lower rails by quick release pins during engine removal or installation. This prevents possible damage to the load cells.

Electrical and optional hydraulic terminal panels. Electrical and hydraulic terminal panels are mounted to the rails of the engine thrust trailer. These panels provide a centralized location for all connections of systems between the engine being tested and their respective indicating instruments and controls in the cab.

The electrical terminal panel assembly, figure 4-3, is an electrical junction box for interconnection of all circuits and cables to the engine under test. A compartment of this terminal panel contains the synchro-type pressure transmitters used for measurement of engine fuel and lube oil pressures.

The engine hydraulic terminal panel assembly, figure 4-3, contains the hydraulic load bank for testing three engine mounted pumps. The hydraulic load bank consists of the necessary manifolds, valves, accumulators, flow transducers, and pressure transmitters to maintain hydraulic flow to and from the pumps. The accumulator relieves surges in the system from fast-acting valves.

Pneumatic system. The compressed air system provides a means of pressurizing (20–30 psi) the hydraulic reservoir (located in the optional hydraulic trailer) and supplying air to cool the vibration pickups. The system consists of a motor-driven air compressor, air filter-water separator, air tank, pressure relief valve, pressure regulator valve, and three-way valve. Operation of the system is controlled by a switch located on the control console. The system is capable

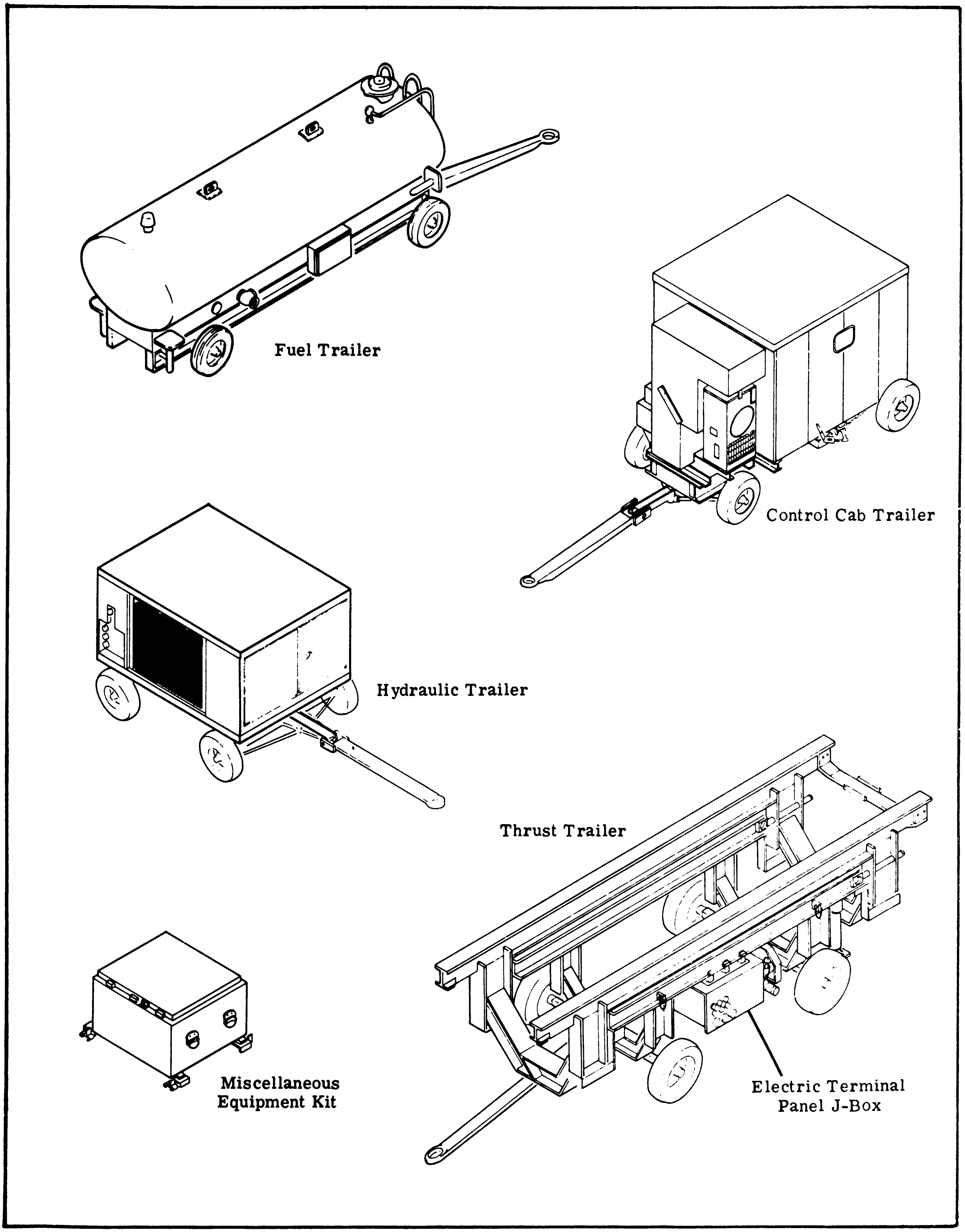
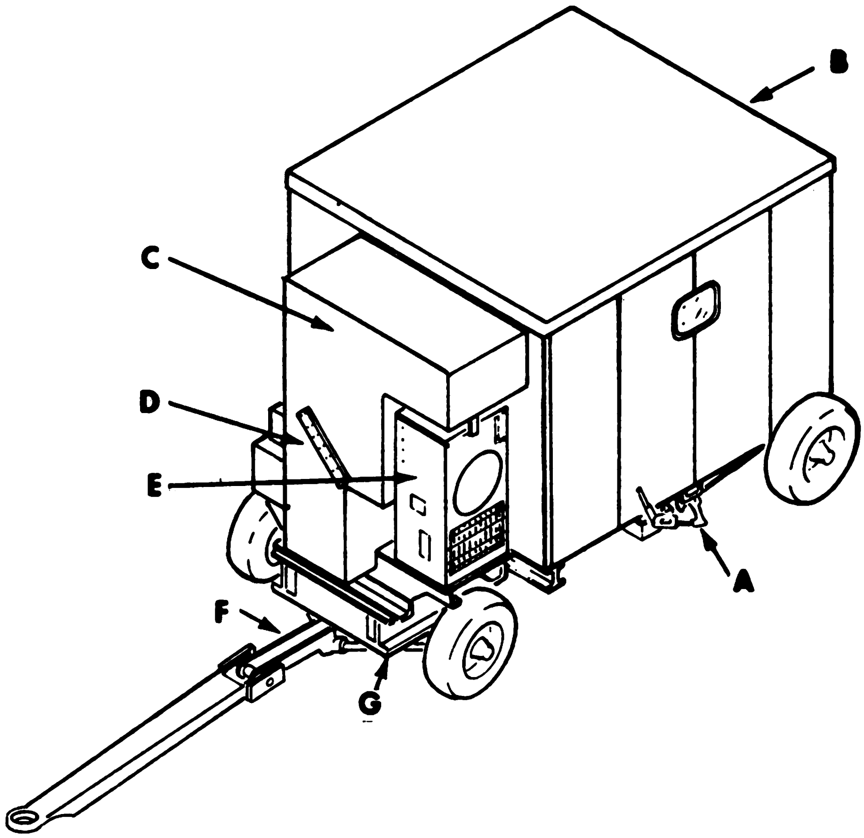


Figure 4–1. A/M 37T–20 aircraft jet engine test stand.



A. Parking brake
B. Control cab
C. Air-conditioner duct
D. Air-conditioner filter
E. Air-conditioner
F. Tow bar
G. Frame

Figure 4-2. Control trailer.

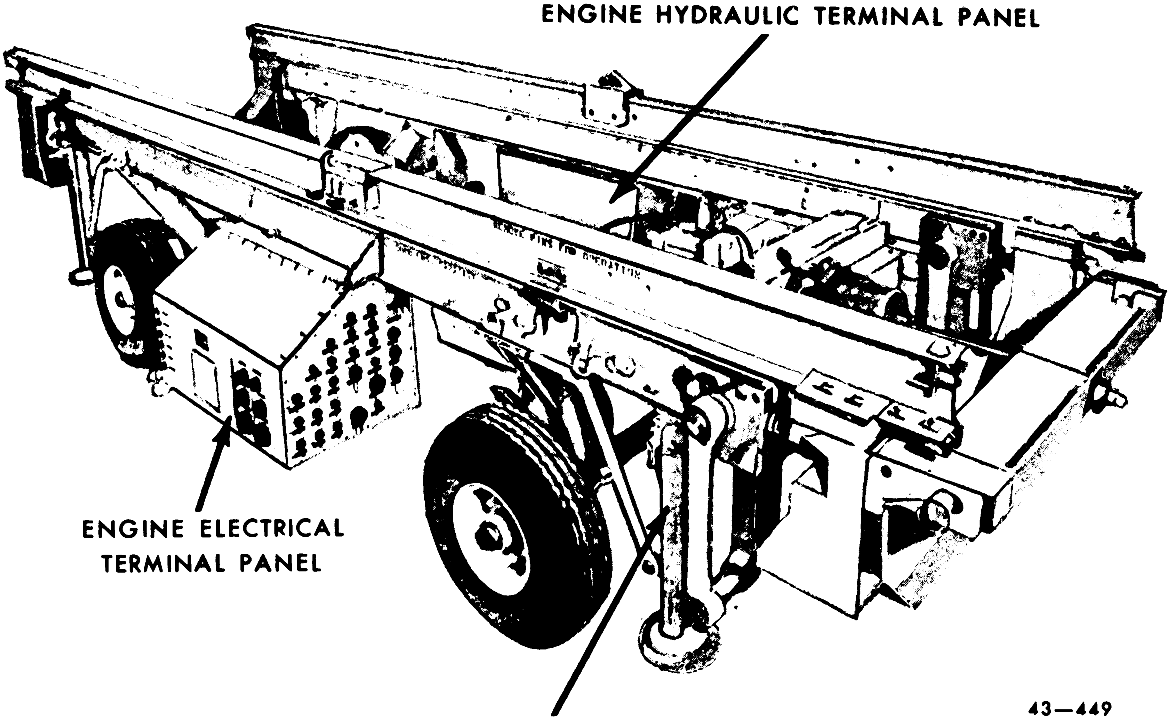


Figure 4–3. Engine thrust trailer.

of delivering 3.5 cubic feet per minture (cfm) of air at 100 psi.

Fuel tank trailer. The fuel tank trailer, figure 4-4, is a basic four-wheel trailer with the structural chassis for mounting the 2500-gallon capacity fuel tank, item A, and fuel supply piping, item C. The front axle is steerable with a tow bar and the rear axle has individual parking brakes. There are four adjustable support jacks, item B, used to stabalize the trailer whenever fuel is in the tank. The trailer is not designed to be used to transport fuel.

The 2500-gallon aluminum fuel tank is mounted on the trailer chassis. The fuel tank is equipped with a float-type liquid level transmitter, 10-inch fill cap, breather vent, drain connections, sight glass, and a sampling cock. The fuel tank shutoff valve is located on the bottom of the tank and is spring loaded closed. The actuating lever for the shut-off valve is located at one end of the tank and connected by a cable. There is a single point refueling adapter provided for tank refueling or paralleling with another tank.

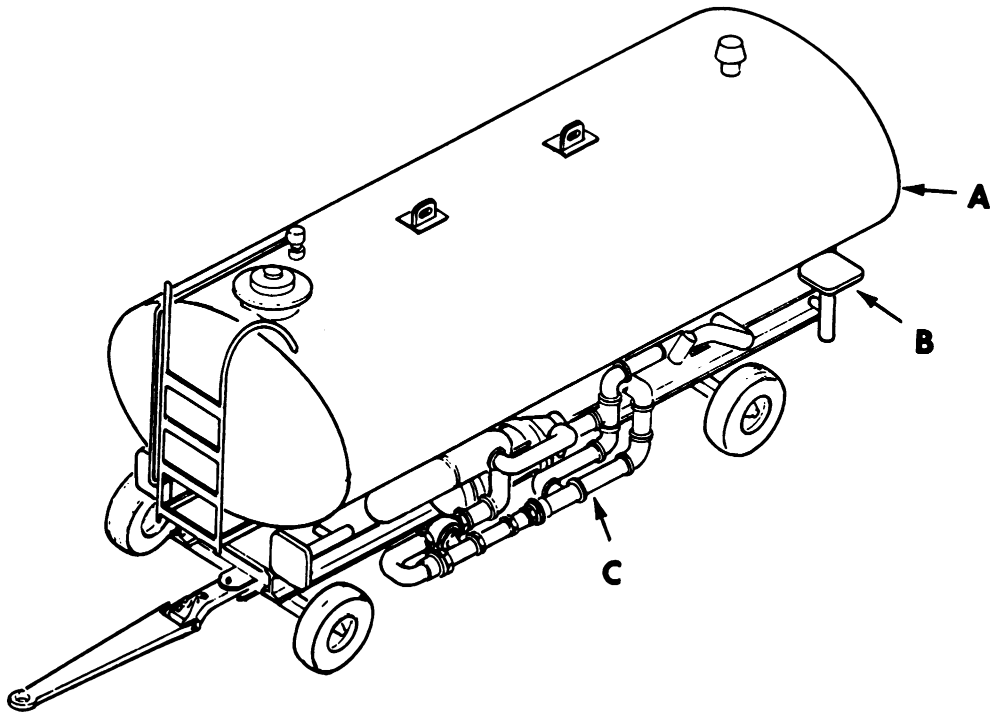
The fuel pump module, mounted on the fuel trailer, includes a 195 gallons per minute (gpm) centrifugal pump and a 10-micron fuel filter, pump bypass check valve, shutoff valve, differential pressure switch, two flow transducer bypass valves, and three fuel flow transducers. If the pressure across the fuel filter becomes excessive, the differential pressure switch will operate a warning light on the control console to indicate that the filter is dirty. The system is so designed to provide gravity flow in the event of electrical power failure. Only idle operation may be sustained with gravity flow.

Miscellaneous equipment kit. The miscellaneous equipment kit, figure 4-1, contains all miscellaneous loose equipment furnished with the test stand, except the fuel hose assembly. The roller mounted transit case has compartments which are complete with tiedown provisions for the electrical terminal box, hydraulic terminal panel, calibration fixture, tiedown pad, thrust restraining linkage (except rods), interconnecting hose and electrical cables, and other miscellaneous small components.

Exercise (467):

1. Match the letter corresponding to the facts in column B with the major item of equipment they describe in column A. Some major equipment in column A have multiple answers. Some facts may not be used.

Column A	*Column B*
___ (1) Fuel tank trailer.	a. 2500-gallon capacity.
___ (2) Control trailer.	b. Individual rear brakes.
___ (3) Thrust trailer.	c. 35,000-pound capacity.
___ (4) Hydraulic trailer.	d. Flexure plates.
___ (5) Electrical and panels.	e. Fuel pump module.
___ (6) Miscellaneous.	f. Air conditioner.
___ (7) Pneumatic system.	g. Electrical junction box.
	h. Maintain hydraulic flow.
	i. Air filter-water separator.
	j. Thrust restraining linkage storage.
	k. Allows wheel removal.
	l. Optional equipment.



A. Tank
B. Support jack
C. Fuel supply piping

Figure 4-4. Fuel trailer.

468. Identify the units which are controlled by the EGT selector switch and name the three ranges of operation displayed by the fuel flowrate indicator.

EGT Selector. The EGT selector, figure 4-5, allows selection of the inputs from 17 individualized chromel-alumel thermocouples, an average of these thermocouples or an average of the thermocouple harness. The selector, item A, is a 20-position switch which has provisions for the connection to the exhaust gas temperature individual indicator. Positions 1 through 17 are for the individual thermocouples, and position 18 is used to read the average of the engine harness temperature.

There are two toggle switches on the selector. The switches are used to control which signals are sent to the indicator. The digital/analog switch, item B, should always be in the DIGITAL position on an A/M37T-20 test cell. The individual/average individual switch, item C, permits the 17 individual readings or an average of these readings to be sent to the indicator.

EGT Individual Indicator. The EGT individual indicator, figure 4-6, provides a display of the temperature readings sent to it by the selector switch. The indicator gives a digital readout, item A, in degrees Fahrenheit. The light emitting diode (LED) has a display range of 0 to 2400°. The indicator samples the EGT at intervals of 0.5 to 3.0 seconds. The rate adjustment knob, item B, on the front of the indicator provides the means of varying the sampling rate.

Fuel Flow Rate Indicator. The fuel flow rate indicator, figure 4-7, is a three-range digital indicator which measures engine fuel flow in pounds per hour (pph). The indicator shows which range is being monitored by illuminating the appropriate turbine light, item C, on the front of the indicator. The ranges are:

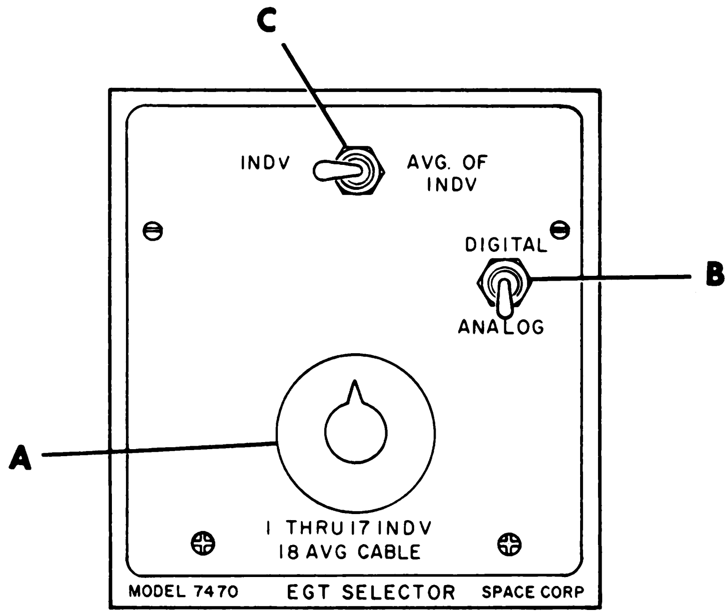
- Range 1 - 0 to 750.00 pph.
- Range 2 - 0 to 7500.0 pph.
- Range 3 - 0 to 75000 pph.

The decimal point in the readout, item A, automatically shifts as the range changes. The indicator automatically controls the solenoid valves in the fuel module to divert fuel flow through either the 1/2-inch, 3/4-inch, or 2-inch flow turbines.

Temperature variations have an extreme effect on specific gravity. The nominal specific gravity of JP-4 is 0.777 when measured at 60° F. This figure may be used for most engine tests. When critical measurements are required, such as an engine with fuel flow problems, the specific gravity of the fuel in the tank should be measured. A hydrometer is used to measure the specific gravity and this value is used to set the specific gravity thumb switches, item D.

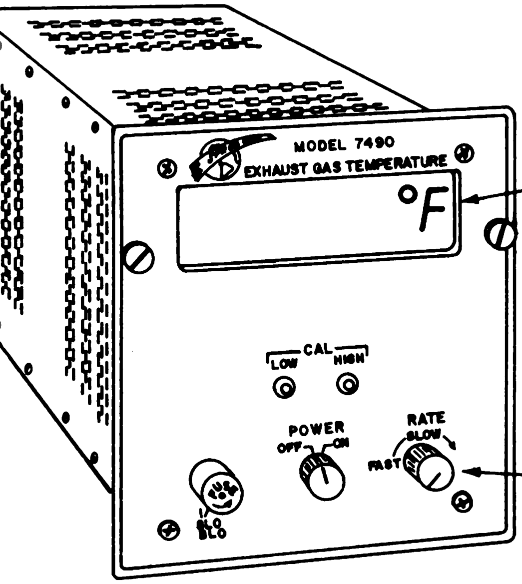
Exercises (468):

1. What is the switch position required to obtain individual thermocouple readings?



A. Selector switch
B. Digital/analog switch
C. Individual/average of individual switch

Figure 4–5. EGT selector.



A. Digital indicator
B. Rate adjustment knob
Figure 4-6. Exhaust gas temperature

Vhat position should the digital/analog switch be in on ne AM37T-20 test cell?

Vhat are the three positions of the fuel flow rate ndicator?

Identify what is displayed by the N_1 and N_2 speed cator, specify why it is important that the percent speed is correctly entered, and state the peratures the IC temperature indicator will display.

and N_2 Speed Indicator. The engine speed indicator, e 4-8, is a combination digital and analog indicator. It is ble of measuring engine rotor speeds of up to 70,000 in either actual rpm or percent of engine speed.

operate the indicator, it is extremely important that the percent engine rpm is dialed in on the thumb switches, A. While the number you dial in does not effect percent m readings, it will have a big effect on the accuracy of ngine speed indication on the digital indicator, item C. instrument is accurate to within ±2 rpm when the ct 100 percent is dialed in.

ne analog indicator, item B, measures engine speed in ent of rpm. This continuous readout is independent of ligital display.

C Temperature Indicator. The IC temperature ator, figure 4-9, measures inlet air, anti-icing, fuel, and oil iron-constantan thermocouple temperature. It displays these temperatures on a digital indicator, item A, in degrees Fahrenheit with a range of −50 to +1600°.

On the front of the indicator, there is a 20-position switch, item B, to select the desired reading. The analog/digital switch, item C, transfers the lube oil indication from the analog indicator on the control panel to the digital indicator on the instrument. With the switch in the DIGITAL position, the display will show the lube oil temperature regardless of the position of the selector switch. In this position the oil temperature indication is the most accurate.

Exercises (469):

1. What is indicated on the N_1 and N_2 rpm indicator?

2. Why must the correct 100-percent rpm be entered on the indicator?

3. What temperatures are displayed by the IC temperature indicator?

4. If you wish to read the lube oil temperature on the digital indicator so you can obtain greater accuracy, what must you do?

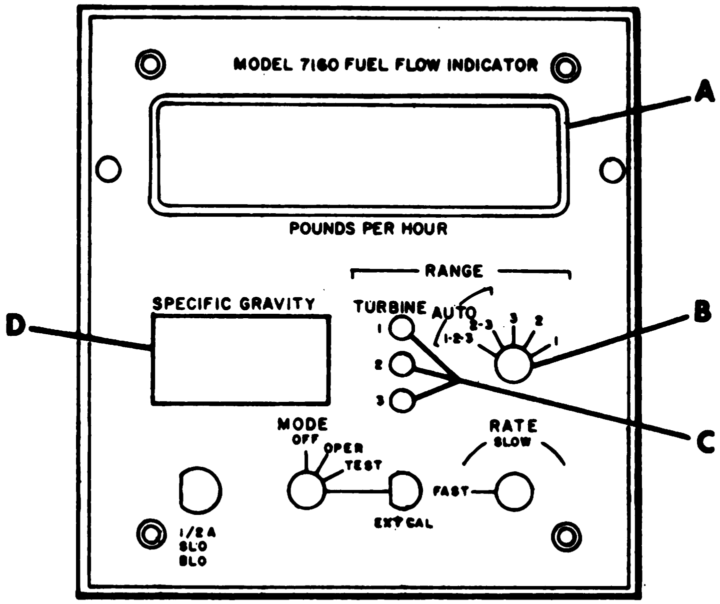
4-3. Use of Ground Power Equipment

Powered aerospace equipment must have rules of safety to insure safe operation. Before anyone operates this equipment, he or she must be checked out by an aerospace equipment technician or other qualified person in the safety procedures and normal operating limits.

470. List the servicing inspection required before you operate the MA-1A compressor and tell whether hypothetical readings for oil pressure, rpm, and exhaust gas temperature of the MA-1A are within operating limits.

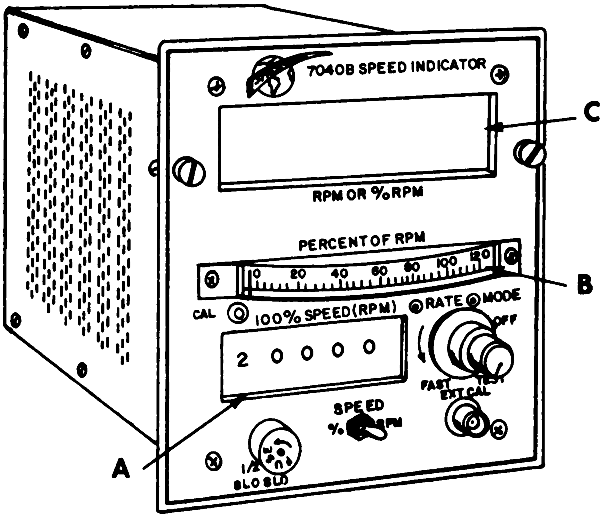
MA-1A Compressor Service Inspection. The service (preoperational) inspection consists of several steps. First, you must check the AFTO Form 244, System/Equipment Status Record, to see if any discrepancies have been entered by flight line personnel. Next, you must visually inspect the entire unit for loose wiring, leaks, loose components, etc. The unit must also be serviced as required with oil and fuel.

Minor maintenance may also be performed during the service inspection. Any problems which cannot be repaired immediately must be entered on the AFTO Form 244. Major discrepancies and safety hazards must also be entered on the AFTO Form 244. The unit must then be removed from service and reported to the maintenance section at once. This



A. Digital readout
B. Turbine range selector
C. Turbine lights
D. Specific gravity thumb switches

Figure 4–7. Fuel flowrate indicator.



A. 100% thumb switches
B. Digital indicator
C. Analog indicator
Figure 4–8. N–1 and N–2 speed indicator.

will insure that the unit is scheduled for repair as soon as possible.

Operating Limitations. To start the MA–1A engine, turn the master switch to RUN and position the start switch to ON (this switch is spring loaded to the OFF). When the master switch is on, the fuel boost pump motor is energized. When the start switch is positioned to RUN, the starter will spin the main shaft causing the compressor and turbine assembly to rotate. A sound will indicate operation of the boost pump motor and spinning of the main shaft.

Monitor the exhaust gas temperature gage and tachometer. Lightup or ignition should occur at about 2 or 3 percent speed. It will be indicated by a rise in exhaust gas temperature. If light up does not occur, turn the master switch to STOP and try to determine the cause. If you cannot locate the cause place a write up in the AFTO Form 244 and call for another unit. The main fuel supply should cut in before 20-percent speed, giving another rise in temperature. Speed should continue to rise smoothly and evenly from this point. In the speed range of 20 to 25 percent, the exhaust gas temperature will swing over into the red zone, but under normal conditions it will move back to a cooler range in a few seconds. If the temperature rises above 1250° F. turn the master switch to STOP immediately to stop the engine. Or, if the unit does not exceed 35- to 45-percent speed in 30 seconds, move the start switch to OFF and wait 4 minutes before attempting another start.

A rise in oil pressure should be indicated between 20- to 25-percent speed, and it should be over 20 psi by the time the engine has reached 95 percent. The engine speed should be 95 percent within 30 seconds. The speed should not rise above 103-percent maximum and should stabilize at 100 to 101 percent. If the exhaust gas temperature gage needle hits the pin at the end of the red zone during acceleration, immediately turn the master switch to OFF to stop the engine. When the engine is at a stabilized rpm, the exhaust gas temperature should be 811° F. plus ambient temperature. The ammeter should read 20 to 25 amps until the battery is fully charged, and then it should read approximately 0.5 amps. The load light will come on at approximately 95 percent, indicating the unit is ready to deliver air.

When air delivery takes place, the speed gage or tachometer should drop from 99 to 100 percent, and the exhaust temperature should rise about 100° F. The air pressure gage should read not less than 25 psi. When the load valve closes to stop air delivery, the speed should rise from the 100- to 101-percent range and the exhaust temperature should drop to normal operating range. The air pressure should drop to below 5 psi.

To stop, allow the MA–1A to stabilize after the load valve closes. Let the unit run from 3 to 5 minutes, and then position the start switch to STOP. Turn the master switch off. Then close the instrument panel door, but leave the intake and exhaust doors open for 30 minutes after a run. Disconnect and store the airhose.

Exercises (470):

1. List the servicing inspection requirements prior to operation of the MA–1A.

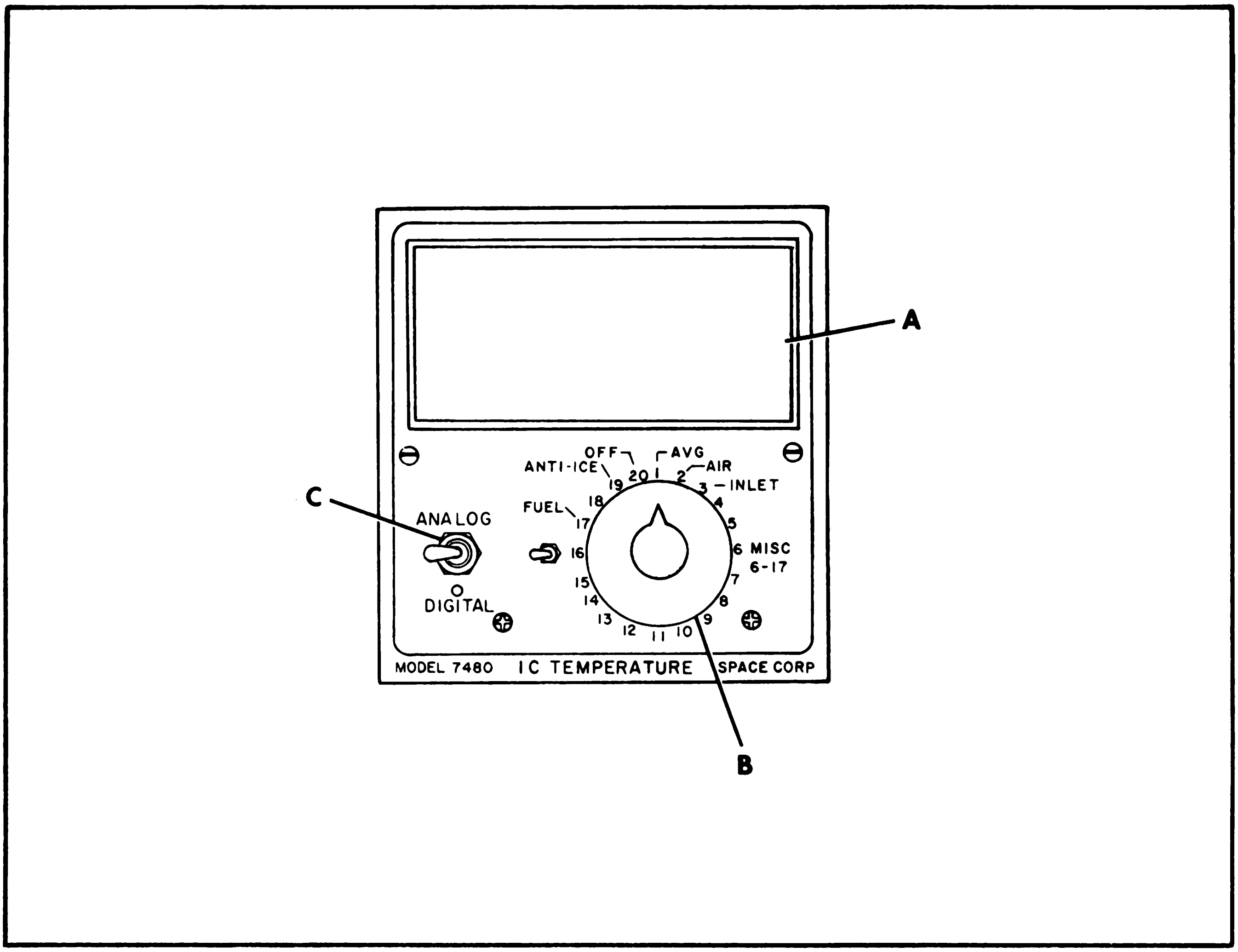
2. When starting an MA–1A compressor, the tachometer indicates 25 percent, EGT 200° CAZ., and oil pressure 10 psi. Is the unit within normal starting limits? Explain.

471. List the preoperation inspection requirements for the MD–3A generator and differentiate between the AC and DC connectors.

Servicing Requirements. The MD–3A generator is essential for testing jet engines. We need the preoperation inspection to lengthen the generator's life and your test facility's effectiveness. Be sure the AFTO Form 244 does not contain any disabling discrepancies. Also, check for loose connections of the wiring, detached or loose components, leaks, and oil and fuel systems properly serviced. Be positive the power cables are not broken and if the connectors show excessive wear, have a qualified AGE mechanic replace them.

Power Cables. The DC power cable supplies power from 500-ampere generators mounted on the engine gearbox. Connected to the back of the control cab, the DC system provides power at the correct voltage and amperage to operate the DC electrical system. The power goes through the inverter for instrumentation. Power is also supplied to the emergency stop button, breakaway switch, battery charger, and 24 volts DC emergency battery. The DC cable is readily recognizable by the oval plug.

The AC power is produced by a 400-cycle generator mounted on the gearbox with the DC generators. The AC system connects to the auxiliary cab on the fuel trailer. The connecting plug is rectangular. It supplies power for the



A. Digital indicator
B. Selector switch
C. Analog/digital switch
Figure 4–9. IC temperature indicator.

heater and air-conditioner, hydraulic heat exchanger, hydraulic boost pump motor, fuel pump motor, and air compressor motor.

Exercises (471):

1. What are the preoperation inspection requirements on an MD–3A generator?

2. How can the AC and DC connectors be differentiated?

4-4. Use of Vibration Analyzer

To analyze vibration problems, you must have a thorough understanding of the vibration characteristics of the engine being analyzed. To a degree, these characteristics vary from one engine to another, but there are fundamentals that are applicable to all jet engines. These fundamentals form the foundation of knowledge that is essential for an understanding of vibration problems. The following explanation will help you understand these fundamentals.

472. Identify the two types of vibration and define the terms associated with jet engine vibration.

Types of Vibration. It has been generally accepted that there are two major types of vibration in a jet engine. They are called forced vibration and externally excited vibration. To further classify vibrations, they can be called either transient or steady state vibrations.

Forced vibration. The source of vibration which usually causes most concern is classified as forced vibration. Forced vibration in an engine is attributed to an unbalanced condition in one or more of its moving parts. Unbalanced

means that there is unequal distribution of mass about the axis of rotation. In figure 4-10 you can see that as the part rotates the heavy side, point A, will be displaced from its normal path because of centrifugal force acting on it.

Since all moving parts within the engine are supported by bearings, which are in turn contained within the engine supporting structures, the vibrations may be transmitted to various other parts of the engine.

Some sources of forced vibration are: unbalance, misalignment, eccentricity, excessive clearance, and defective bearings. Interference of parts and bent or crooked shafts are other mechanical faults.

Externally excited vibration. Another type of vibration is externally excited vibration. Examples are combustion roughness, air turbulence at intake or exhaust, loose engine mounts, and hydraulic system chatter. This type of vibration is not usually destructive in nature; but if the engine is installed, pilots may sometimes become apprehensive where they experience a vibration of this type and their first thought is of engine malfunction. This is the type of problem that causes unnecessary engine removals and unwarranted repairs. If proper vibration analysis is used, the source of vibration can be pinpointed and unnecessary maintenance can be avoided.

Transient and steady state vibration. While these are not types of vibration, they must be considered during vibration analysis. Both can be found during either forced or externally excited vibration.

a. Transient vibration exists but does not persist long enough to be measured. In other words, it comes and goes. Transient vibration is usually externally excited.

b. Steady state vibration is one that exists and persists until the source that is causing it is removed. This type of vibration can be caused from a forced vibration or an externally excited vibration.

The worst possible vibration, the one that can do the most damage to the engine, is steady state forced vibration.

Terms Used in Vibration Analysis. The number of cycles completed in a given time is called frequency. Frequency is usually measured in cycles per second, hertz (Hz). Since the number of cycles completed in a given time is determined by the number of revolutions completed, frequency is related to the rpm of the part causing the vibration. The compressor, turbine wheel, and shaft constitute the bulk of the rotating masses in the engine and their rpm is that of the engine. Thus, the predominant or primary engine frequency is equal to engine rpm. The accessory gears and components rotate at different rpms due to gear reduction. Therefore, the secondary frequencies are at accessory drive rpms.

Amplitude. Amplitude is a measurement of the displacement from the axis of rotation. Amplitude is measured in mils (1 mil = .001 inch). In figure 4-11 you will note that the point of unbalance was displaced first in one direction, and then the other. In other words, the total peak-to-peak displacement was twice the amplitude, or double amplitude.

Phase. The phase is a quantity which denotes the stage of progress of the cycle. It is often expressed as an angle or as a fraction of a complete cycle. Thus, if a cycle is one-half completed, the phase would be one-half of 360°, or 30°.

Phase lag. The phase lag is the angular lag between the actual heavy spot and the place around the rotating part that is actually displaced while the vibrating movement is occurring. This lag normally varies between 0 and 180°.

Resonance. Every object has a natural frequency of vibration. When the frequency of the forced vibrations is the same as the natural frequency of the body, we have a condition known as resonance. This causes the free vibrations to reinforce the forced ones. Since every attempt is made to design engine components with natural frequencies below or above normal operating range, we might conclude that resonance is a problem with which we are not concerned.

However, we must remember that through long service or extensive rework certain parts of the engine can be altered considerably. This can result in changes in design characteristics that will produce resonant vibrations in the normal operating range. The speed at which resonance occurs depends on the mass of the rotating system, the rigidity of the system and its supports, and other factors. Phase lag is theoretically 90° at resonance.

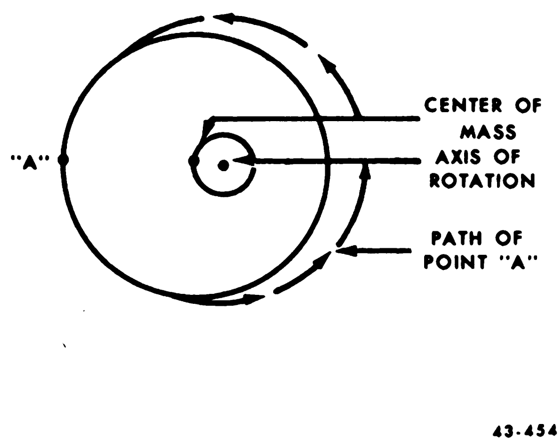


Figure 4–10. Forced vibration.

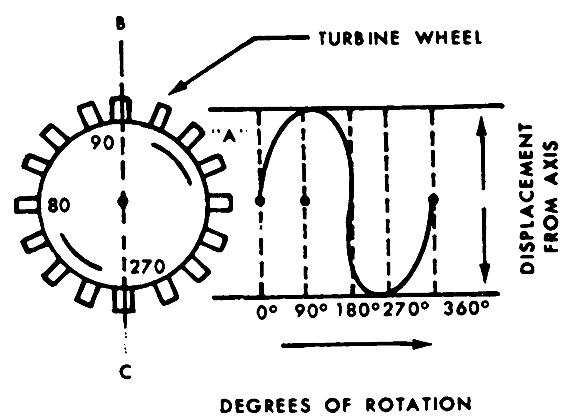


Figure 4–11. Displacement sine wave.

As to the relationship of resonance to amplitude, you will remember that the free vibrations reinforce the received ones. Thus, when we experience a problem with resonant vibration, we can expect that the amplitude will be extremely high. In fact, amplitude may be much higher at lower operating speed with resonant vibrations than at lower operating speed, although the forces due to imbalance are greater at a higher speed.

Exercises (472):

1. Name the two types of vibration experienced in jet engines.

2. Define the following terms.
   a. Frequency.

   b. Amplitude.

   c. Mil.

   d. Phase.

   e. Phase lag.

   f. Resonance.

473. State the principle on which jet engine vibration analysis is based and tell what occurs when there is a change in the mechanical condition of an engine.

Principles of Vibration Analysis. As you learned in the preceding objective, vibration is excited from several possible areas. At the point it is measured, all the forces acting to create vibration present a highly complex pattern. This pattern is further complicated by the fact that the main rotor functions as a flexible, rather than a theoretical, rigid rotor system. Therefore, we can assume that any change in the mechanical condition of the engine will probably be reflected in a change of vibration characteristic. This change may involve amplitude (displacement), frequency, and phase. However, this change in characteristic may not be observed if only one parameter of vibration such as total displacement is measured. For example, displacement may be exactly the same in two completely different problems, but it is unlikely that all parameters would be the same. For this reason, it is necessary to measure all parameters to identify the vibration source. To illustrate how overall vibration at a given point on an engine is affected, suppose that a forced vibration is caused by an unbalanced turbine and/or compressor rotor. We can see from the theory of freely rotating masses that the rotational axis of the rotor will be displaced from its normal position by an amount which is proportional to the amount of unbalance. However, a compressor or a turbine rotor is not a free-rotating mass. Both are constrained by bearings and bearing supports. Therefore, the unbalance of the rotor causes the bearing supports to vibrate in a given direction or phase at a given frequency and amplitude. This vibration is then transmitted through the engine structure to the pickup point. Consequently, the vibration that is caused by rotor unbalance is affected by the transmitting qualities of the engine structure, as well as the resonant characteristic of the complete structure and its mounts.

Exercises (473):

1. On what basic principle is jet engine vibration analysis based?

2. In all probability, any change in the mechanical condition of the engine will be reflected in a change of what?

474. State the purpose of the vibration analyzer; using figure 4-13, compute for B when the values of A and C are known; and associate functional descriptions of the analyzer front panel controls with the names of the control.

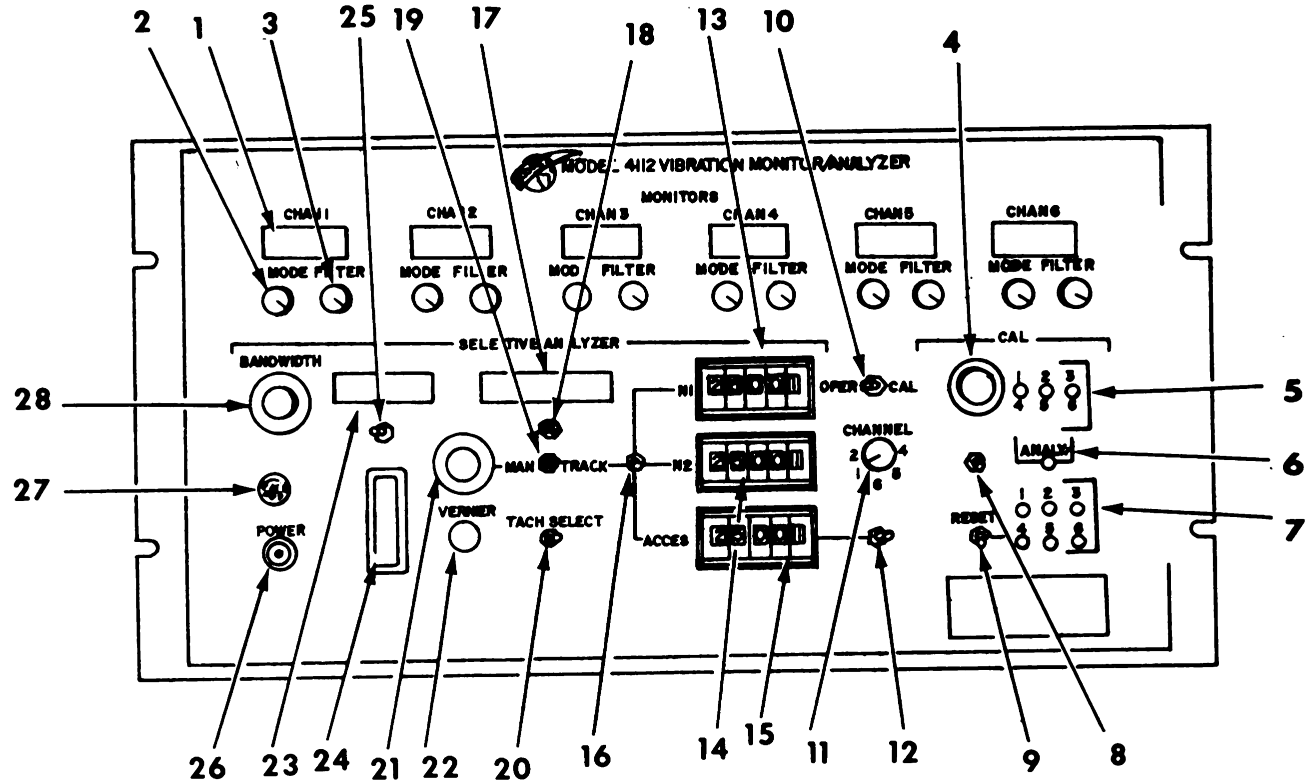
Vibration Analyzer. A vibration analyzer, figure 4-12, is available in the control console for determining which specific part or unit of the engine is vibrating. To identify the functional description of the front panel controls, digital indicators, and the analog meter, let us take each one separately.

Three-digit digital display indicators. There are six lighted display indicators, item 1, to provide a three-digit readout for each of the six vibration channels.

Mode selector switch. This switch, item 2, matches the analyzer to the type of pickup or accelerometer you have on the engine.

Filter selector switch. This switch, item 3, allows selection of the filter necessary to remove the natural vibration frequencies of each specific type of engine.

Pickup sensitivity adjustments. Before operating the analyzer, you have to calibrate the analyzer to each of the pickups. To do this, place the sensitivity/alarm switch, item 8, to sensitivity and the oper/alarm switch, item 10, to CAL. Place channel selector switch, item 11, to channel being calibrated. Set the vibration pickup sensitivity control, item 4, to the calibration frequency of the pickup. Now adjust the potentiometer, item 5, so that 25.0 is displayed for that



1. 3-digit display indicator
2. Mode selector switch
3. Filter selector switch
4. Pickup sensitivity control
5. Potentiometer
6. Analyzer potentiometer
7. Alarm potentiometer
8. Sensitivity/alarm switch
9. Alarm reset button
10. Oper/alarm switch
11. Channel selector switch
12. Tach selector switch
13. Thumb switches
14. Thumb switches
15. Thumb switches
16. Selector switch
17. Center frequency indicator
18. Frequency/rpm switch
19. Mode selector switch
20. Tach selector switch
21. Course vernier dial
22. Fine vernier dial
23. Amplitude digital indicator
24. Amplitude analog indicator
25. Analog multiplier
26. Power button
27. Fuse
28. Bandwidth selector

Figure 4–12. Vibration analyzer

channel. Then adjust the analyzer potentiometer, item 6, to display 25.0 on amplitude digital indicator, item 23. Follow this same procedure for each of the channels which are being used on the engine you are operating.

Alarm set. The vibration analyzer has an alarm which will cause the channel indicators to flash. You must set the alarm at the value you wish to monitor, most likely the maximum vibration limit for that engine location. To set the alarm, you first place the sensitivity/alarm switch to ALARM. Adjust each of the alarm potentiometers, item 7, to the value listed in the technical order for your engine. Anytime the alarm setting has been exceeded, the channel indicator will flash to indicate to you that there was excessive vibration. The channel indicator will continue to flash until the alarm reset button, item 9, has been pressed.

Thumb switches. The thumb switches (items 13, 14, and 15,) are used to determine exact frequencies of rotating components. The tachometer (tach) ratio for the N_1 and N_2 compressors must be dialed in on the thumb switches. When you wish to track a particular accessory, you must then dial in the correct tach ratio on the accessory thumb switches.

Digital indicator, center frequency. This indicator, item 17, is a five-digit LED indicator. This indicator will show either frequency or the rpm of a component. Switch 18 determines whether frequency or rpm is to be displayed. Selector switch 16 determines which rotating component is displayed. The mode selector switch, item 19, when in the TRACK position, will automatically track either frequency or rpm of the component determined by switch 16. In the MANUAL position, you may now isolate a specific

vibration frequency. This is done by first placing switch 25 in the X5 position. This multiplies the actual signal strength by five. The multiplied signal is then displayed on the amplitude digital indicator, item 23, and the amplitude analog indicator, item 24. Adjust the course and fine vernier dials, items 21 and 22, until the highest amplitude reading is indicated on items 23 and 24. Then place the bandwidth switch, item 28, to NARROW. Readjust the fine vernier to obtain the highest amplitude. Now place switch 25 in X1 position. The amplitude shown on the amplitude digital indicator is the exact vibration amplitude, and the reading on the center frequency meter is the frequency within 2 Hz of the rotating components.

Computation of Component Frequencies. The speed of most modern turbojet engines is measured in percent rpm. At times during vibration analysis, it will be necessary for the operator to use various formulas to determine the source of vibration. For ease of computing the values needed, formulas are established using triangles. See figure 4-13 for examples on how to use triangle formulas.

Exercises (474):

1. What is the purpose of the vibration analyzer?

2. Compute for B when A = 20 and C = 5. (Use fig. 4-13.)

3. Match the letter of the functional description in column B with the front panel controls in column A. Some functional descriptions will not be used.

A=B×C OR C×B

B=A÷C

C=A÷B

6=2×3 OR 3×2

2=6÷3

3=6÷2

Figure 4–13. Computation formulas.

Column A

____ (1) Three-digit digital display indicators.
____ (2) Filter selector.
____ (3) Sensitivity/alarm switch.
____ (4) Channel selector.
____ (5) Analyzer potentiometer.
____ (6) Alarm reset button.
____ (7) Thumb switches.
____ (8) Center frequency indicator.
____ (9) Amplitude digital indicator.
____ (10) Amplitude analog indicator.
____ (11) Vernier dials.
____ (12) Bandwidth switch.
____ (13) Mode selector switch.

Column B

a. Selects narrow or wide bands.
b. Indicator light.
c. Adjust amplitude reading on analog meter.
d. Provides readout for the six vibration channels.
e. Used to set alarm value.
f. Tach ratio of compressors or accessory must be dialed in.
g. Displays amplitude numerically.
h. Matches analyzer to type of pickup.
i. Select filter to be used.
j. Uses a needle to display amplitude.
k. Used to set 25.0 on amplitude digital indicator.
l. Shows either frequency or rpm of components.
m. Selects channel to be monitored.
n. Selects inches or milli-inches.
o. Stops displays from flashing.

475. State the reason an rpm formula is required and, using the correct formula, find either the actual or percent rpm.

Rpm Formula. In all of the following formulas, you need to know the actual rpm of the engine. Many times you will only have the percent of rpm and will have to convert that percent to an actual rpm. To use the formula, you must know the rpm of the engine at 100 percent. This information can be found in the intermediate maintenance TO. The tach percent rpm is the rpm indicated on the tachometer indicator. By multiplying these two figures, you can determine the actual rpm the engine is rotating. Figure 4-14 illustrates how the formula is used.

Exercises (475):

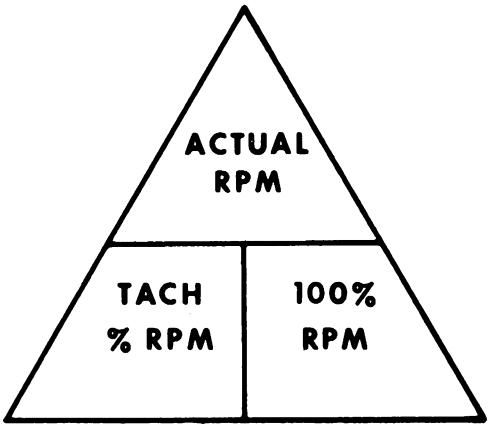
1. Why is the rpm formula needed?

2. Using the formula, find actual rpm when the engine is at 90- and 100-percent rpm is 9700.

3. Using the formula, find percent rpm when actual engine speed is 7070- and 100-percent rpm is 7685.

476. State the purpose of using cycles per second in vibration analysis and use the formula in figure 4-15 to convert rpm to cps.

Cycles Per Second. Vibration level is monitored on the monitor meter. When excessive vibration is persistent, it is necessary for you to trace and pinpoint the exact source of



100% RPM = 9700
TACH % RPM = 80%
ACTUAL RPM = 9700 × 80%
ACTUAL RPM = 7760

Figure 4–14. Rpm formula.

vibration. The frequency dial of the analyzer meter is used to determine the frequency. Frequency can be termed a smaller equivalent or increment of rpm. To convert cps (Hz) to rpm, use the formula and example shown in figure 4-15. After computation, your answer of cps (161.66) can be verified using figure 4-16, line A. Find 100-percent rpm on the bottom of the figure and proceed upward until you intersect line A, which is 161.66 cps.

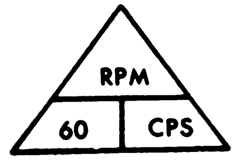
Exercises (476):

1. What is the purpose of using cps in vibration analysis?

2. Convert 5820 rpm to cps. (Use fig. 4-15.)

477. State how tachometer ratio can benefit vibration analysis and use the correct formula to compute the tach ratio of a given unit.

Tachometer Ratio. When the speed of the engine is at a constant rpm, vibration can be tracked and analyzed using the frequency controls. If the vibration level is near the allowable technical data limits, it should be monitored throughout the complete engine test at all power settings. This can be measured by use of tach ratio. Tach ratio can be obtained by using the formula in figure 4-17. The tach ratio can be dialed into the vibration analyzer with the thumb switches, figure 4-12, items 13, 14, or 15, which tunes the analyzer to the exact part or unit in the engine. The vibration



RPM=9700 @ 100%
CPS=_____@ 100%
CPS=9700 ÷ 60
CPS=161.66 @ 100%

Figure 4–15. Convert rpm to cycles per second.

analyzer will now stay tuned to this part or unit throughout all power ranges.

Exercises (477):

1. How can the tach ratio benefit vibration analysis?

2. What is the tach ratio of the hydraulic pump when rpm is 3300 and tach speed is 4200 rpm at 100 percent? (Use the formula in fig. 4-17.)

478. State the requirement for using gear ratio and compute the gear ratio of an accessory using the applicable formula.

Gear Ratio. Because of gear reduction differences in a jet engine, you may be confronted with a vibration created by an accessory mounted on the accessory drive gearbox. Gear ratio can be computed by use of the formula in figure 4-18, given the component speed (CS) and drive speed (DS). From your computation, you can identify the accessory vibrating by referencing the specification table in the intermediate maintenance instructions.

Exercises (478):

1. How is gear ratio used in vibration analysis?

2. Compute the gear ratio for an accessory that has a drive speed of 9700 rpm at 100 percent and a component speed of 4200 rpm at 100 percent.

479. Specify how the formulas are used when the engine is not operated at 100 percent of rpm and, using the proper formulas, compute required information for an engine not operating at 100 percent of rpm.

Using the Formulas. When you are working with the formulas we have just discussed, you will generally use more than one. There will also be times when you want to find out what will or should happen when the engine is operating at a

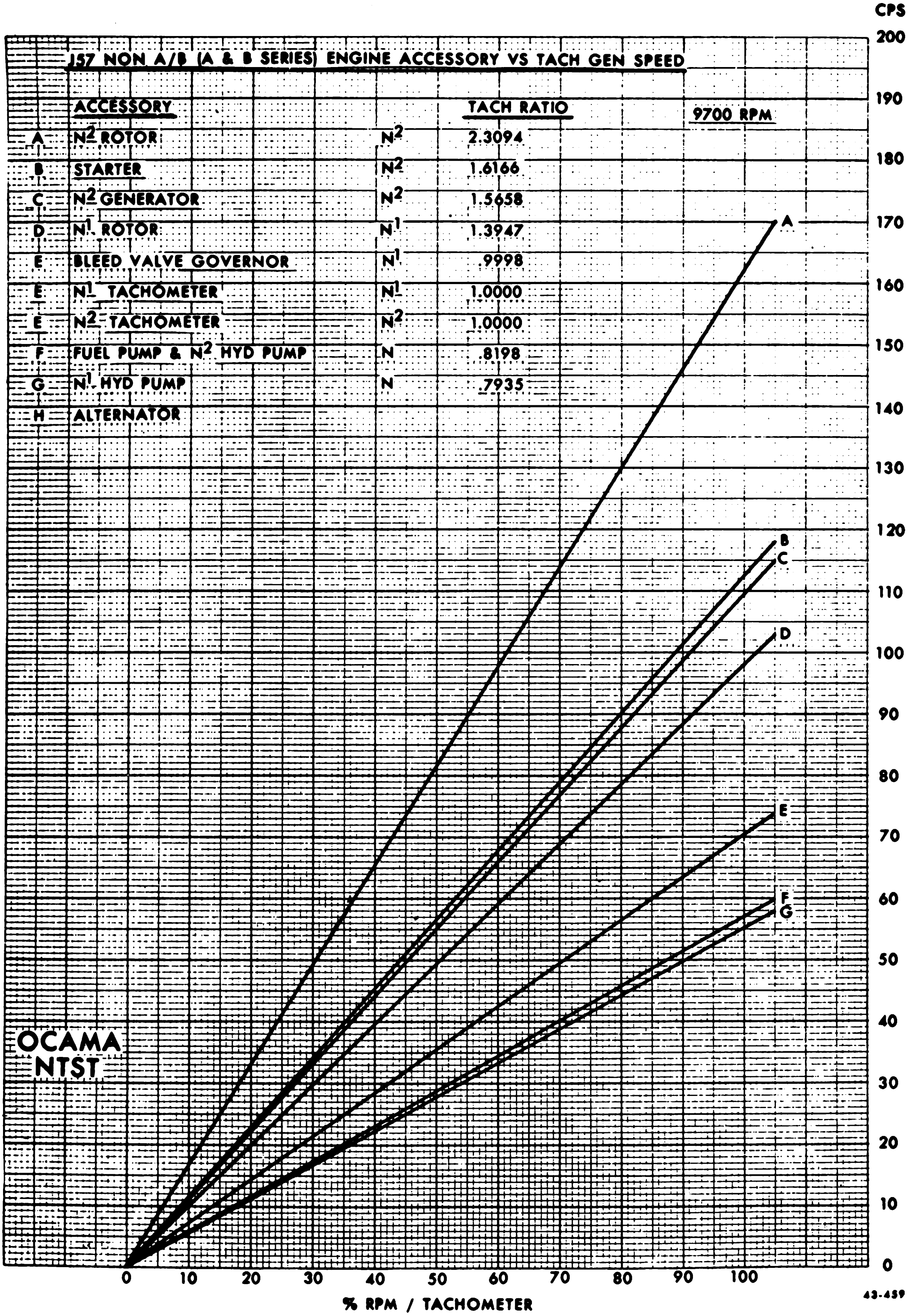
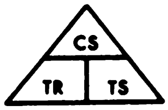
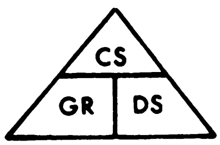


Figure 4–16. Percent rpm/tachometer.



CS=9700@100%RPM
TS=4200 @ 100 % RPM
(ALL AN TACH GENERATORS
TURN 4200 @ 100% RPM)
TR=9700÷ 4200
TR= <u>2.3095</u>

Figure 4–17. Tach ratio formula.



CS=6790 @ 100% RPM
DS=9700 @ 100% RPM
GR=6790 ÷ 9700
GR= <u>.700</u>

43-461

Figure 4–18. Gear ratio formula.

different rpm. To do any of these, you will have to first change the rpm you are using to 100 percent and then use another formula.

As an example of what we have said, if you are running an engine and have a frequency of 137.4 cps at 85 percent rpm, and if you wish to verify that a component was causing the vibration, you might want to check the frequency at another rpm. First, you must know what reading you should have. Using the given information and the formula, you find the actual rpm is 8244. Next, you will have to find out what the 100-percent rpm is using the rpm formula. Here we find the rpm is 9700. Now you would want to find what the rpm should be at another test point, usually at 5- or 10-percent intervals. We will select 5 percent. Again, use the rpm formula to find that at 80 percent the rpm is 7760. You then use the cps formula to find that you should have 129.3 cps if the same part was causing the vibrations. If you do this and the cps is different, then you have not identified the correct item.

Exercise (479):

1. When operating an engine with a 100 percent rpm of 7685, at 80 percent you have a vibration of 102.5 cps. To test this, you wish to advance the throttle to 85 percent.
   a. What is your actual rpm?
   b. What should the cps be if the same component is causing the vibration?
   c. What is the tach ratio for this component?

4-5. Engine Installation and Removal

Because of the variations in construction and various types of test stands and thrust beds, precise installation instructions cannot be listed for all engines. You must become familiar with the applicable TO for your particular installation and refer to it for installation, testing, and removal for your specific engine.

480. State what must be accomplished before engine installation and the purpose of the test stand-to-engine adapters.

Engine Installation. Before you install an engine, you must make sure that rail adapters for the engine and stand are compatible and correct for your engine. These adapters support the weight of the engine and secure it to the thrust trailer. The rail adapters aid in transferring the engine from the transportation trailer into the thrust trailer. By taking the precaution of securing the upper and lower rails of the thrust bed before transferring the engine, you will prevent damage to thrust bed load cell. After the engine is properly supported, secured, and restrained, you may install the applicable engine control kit and miscellaneous equipment.

Exercises (480):

1. What are the necessary steps of preparation prior to engine installation?

2. What is the purpose of the test stand-to-engine adapters?

481. Specify what article of miscellaneous equipment is not in the kit and check the steps of a hypothetical installation situation.

Equipment Installation. The miscellaneous equipment kit provides all miscellaneous loose equipment necessary for the test stand except the fuel hose assembly. During installation of your required kit and equipment, use the applicable TO as a guide to show the specific attachment points and special instructions.

In preparing to install the equipment kit, the following guide may save you time and trouble:

a. Place the kit parts in appropriate order to facilitate inventory and inspection.

b. Visually inspect all parts for damage which may have been incurred during previous installations.

c. Check all indicators and controls for damage and secure attachment. Hand-operated controls and switches should operate freely.

The time you spend inspecting these parts is fully justified and worthwhile. Inspection can reduce the occurrence of unexpected equipment malfunctions. This care can also increase engine reliability and performance.

Exercises (481):

1. What miscellaneous equipment does the kit include?

2. At the completion of your installation of an engine in the test stand, you start the engine. Parts were inspected and found serviceable, and indicators and controls were secure. Most instruments indicate normal readings, but the tachometer fails to operate. What step was not performed on the installation procedure?

482. State the sequence for removing miscellaneous equipment and for removing the engine from the thrust trailer.

Equipment and Engine Removal. Engine and test equipment removal consists of the steps required to remove the engine and all test equipment, control panels, and electrical cables from the test stand and restore them to their proper places. The steps in the removal of the engine and test equipment are the reverse of the installation sequence. When you become familiar with the equipment, each task will be easier and less time consuming so that the removal of test equipment becomes almost automatic to you. Efficiency at a test facility is extremely important. Few Air Force missions can afford a breakdown or slowdown of test cell equipment and operators.

Exercises (482):

1. What procedure do you follow when removing the miscellaneous equipment kit?

2. How is the engine removed from the thrust trailer?

4-6. Test Facility Maintenance

Since regulations require inspection of all Air Force equipment, we must have inspections and preventive maintenance programs on various test facilities. Conscientiously performed, periodic inspections can greatly increase the reliability and accuracy of the test facility.

483. Specify the guides ased to set up an inspection program for proper maintenance.

Inspections. Individuals assigned to a test facility are responsible for its proper maintenance. Therefore, you should be familiar with all test cell units which must be inspected, cleaned, lubricated, adjusted, or replaced. Using the applicable TO as a guide, compile a periodic inspection checklist to indicate what is to be inspected at daily, weekly, monthly, quarterly, or semiannual intervals. The checklist should be detailed enough to describe both the unit and the inspection interval. Such checklists provide guides for setting up and maintaining the facility which, as an end result, will give you greater test facility reliability. Each organization may vary the inspection requirement and interval because of local command option.

Exercises (483):

1. What program seeks primarily to increase the reliability of your test facility?

2. What guides can you use for your test facility maintenance?

484. Name the two types of inspections used on the test cell and state how the periodic inspection scheduled is determined.

Periodic Maintenance. Fortunately, beginning engine trouble is often predicted by the engine test cell instruments well in advance of serious difficulty. Many potential problem situations can be quickly and correctly analyzed and remedied if the engine test cell readings and the engine

SCHEDULE	EST AVG OPER HOURS PER MONTH	CALENDAR INSPECTION INTERVAL
A	20	180 DAYS
B	50	90 DAYS
C	75	60 DAYS
D	100	45 DAYS
E	150	30 DAYS

Figure 4–19. Inspection schedule.

malfunction symptoms are interpreted properly. Conversely, misinterpretation of apparent abnormal engine operation and subsequent corrective action may possibly cause serious problems. Consider, also, the possibility of an instrumentation malfunction reflecting false indications of trouble. Proper inspection and maintenance of the test cell will reduce the likelihood of these malfunctions.

Inspections of the test stand and its attaching parts are generally divided into two categories.

Service inspection. Those items which are checked each day before the test cell is used.

Periodic inspection. Those items which are checked on a predetermined schedule.

The periodic inspection is based on a specified number of calendar days, depending on average use. Figure 4-19 shows an example of the way the periodic inspection schedule is determined. To find the estimated average, the operation of the test stand will be monitored for a 60-day period. The average monthly use for this monitored period will be used to select the inspection schedule which is closest to the actual operating hours.

Exercises (484):

1. What are the two types of inspections used on the test cell?

2. How is the periodic inspection schedule determined?

Jet Engine Operational Checks and Adjustments on the Test Stand

PRACTICAL EXPERIENCE in performing a mechanical operation is valuable for developing the skill and confidence needed for efficient on-the-job performance. By disassembling, repairing, reassembling, operating, and adjusting jet engine units, you learn the best and easiest ways to perform the required mechanical operations. As you repeat these mechanical operations, you perform them more easily, rapidly and accurately. To an observer, the job performance of a skilled technician can be fascinating. The technician seems to know exactly how to proceed with the job, what tools and equipment to use, and how to use them. Technicians, knowing these things, waste no time in completing the job.

Operating a test cell is one of the jet engine technician's most important functions. Engines that have been disassembled for inspection, repair or replacement of parts must be tested after assembly to determine whether or not the systems or units are operating properly. The most accurate means that we have for checking the quality of the maintenance performed on an engine is by the use of the test cell. The test cell is our method of bench checking after repair.

It is important that you know the operation of the test cell. Much of the test equipment you use will do part of your troubleshooting for you through the use of lights, gages, and other such devices. When you are learning to perform a test on the engine, the most important thing you can do is study the TO. Read every word. Don't omit any step listed in the text. Many units fail in a test merely because an important step in the TO procedure was overlooked.

This section of the text is written to provide you with as much information as possible. Such information will help you acquire judgement and skill so that you may squarely meet your responsibilities. These responsibilities include operating the engine in the test cell.

In order to understand this subject, you must first become thoroughly familiar with the terms and symbols used. The field of gas turbine engines has a language of its own. Special meanings and definitions are given to common words. The terms used should be familiar to you but if they are not, refer to your technical data for an explanation.

5-1. Test Stand Safety Practices

Before we discuss specific operational checks and adjustments on the test stand, we need to consider safety practices that may save lives and equipment during testing. Hazards are present in everything you do, whether you are marching or eating in the dining hall. Most accidents can be prevented if you take a little time to observe the precautions set forth in the numerous safety manuals published by the Air Force and civilian agencies.

Although your job may not always be the most dangerous in the world, it is the place where you spend a great deal of your time. So that you may become better acquainted with some of the safety precautions that should be observed while working at a test cell, let's briefly review them.

485. Name the safety precautions TO take during engine operation and list the hazards presented by the engine exhaust.

Air Intake. The air intake of most jet engines can develop enough suction to pull a person up to it or partially into it. Whenever you approach any type of operating jet engine, you must keep clear of the intake airstream. Suction near the intake can pull in hats, glasses, loose clothing, and wipe-rags from pockets. Make these articles secure or remove them entirely before you work around the engine.

High-Intensity Noises. All of us know that a jet engine produces a lot of noise. Did you know that not all the noise comes from the exhaust? There is the noise of the rapid expansion of gases in the engine because of the burning of fuel, the vibrations set up on the walls of the combustion chamber and turbine assembly, and the noise of the intake and exhaust air. To all this, add the noise of the afterburner, and you have a noise beyond description.

What is noise? Noise is undesirable sound. It consists of a series of pressure waves (vibrations) traveling at the speed of sound through some transmitting medium. The transmitting medium can be air, though sound may be transmitted through other mediums.

Noises may be loud or soft, high or low. High or low refers to frequency. The frequency is the number of vibrations per second of the sound. The ear responds differently to different frequencies, so that to be heard, a sound of low frequency must be louder than a sound of higher frequency. The ear is most susceptible to damage from loud noises of a frequency around 4000 Hz. As stated earlier, a hertz is a cycle per second. Above this frequency, the efficiency of the ear starts to diminish.

Compressor Bleed Valve. When you check compressor bleed operation or when you work on or near a compressor bleed valve while the engine is running, always take care to stand clear of the valve. When a compressor bleed valve opens, high-pressure air at high velocity is dumped overboard. The force of compressor bleed valve air, particularly when the valve first opens during deceleration from high rpm, is sufficient to knock even a large man off his feet, resulting in possible injury.

Jet Engine Exhaust. Another hazard introduced by jet engines is the high temperature and high velocity of discharge exhaust gases from the tailpipe.

At military thrust, the exhaust may pick up and blow loose dirt, sizeable rocks, sand, and debris a distance of several hundred feet. Therefore, use due caution during engine runup to avoid injury to persons or damage to property. A blast fence is recommended if jet engines are going to be used extensively where there it not a clear space available for dissipation of the exhaust blast.

High temperature may extend up to several hundred feet behind the tailpipe, depending on wind conditions. Closer to the engine these temperatures are high enough to cause bituminous pavement to deteriorate; thus, concrete aprons are suggested for test facilities. Occasionally when a jet engine is started, excess fuel accumulates in the tailpipe. When this fuel ignites, a long flame may extend from the tailpipe due to a momentary overrich condition. Watch out for this hazard and keep all flammable materials clear.

Toxicity. Tests indicate that the carbon monoxide content of jet engine exhaust is low, but other gases are present which have a disagreeable odor and an irritating effect. Exposure usually causes watering or a burning sensation of the eyes. Less noticeable, but important, is the respiratory irritation which exhaust gases may cause. For both these reasons, avoid exposure to exhaust gas, particularly in confined spaces or in pockets where concentrations may build up.

Turbine/exhaust cool down periods. Don't work on the hot section of an engine for at least 30 minutes after shutdown (preferably longer). If work is necessary immediately, wear asbestos gloves. All other sections of the engine may usually be worked on without danger.

Exercises (485):

1. How can you prevent accidents resulting from hazards that you may be exposed to at the test cell?

2. Why should you be especially cautious when you approach an intake of any type of operating jet engine?

3. What precaution should be taken if work must be performed on the hot section of the engine immediately after shutdown?

4. At approximately what sound frequency is the ear most susceptible to damage from noise?

5. List the hazards presented by engine exhaust.

486. State why CO_2 is not a recommended extinguishing agent to use on an engine fire and describe what should be done if an internal fire occurs after engine shutdown.

Ground Engine Fires. Experience has shown that the best method of handling an internal, ground engine fire in turbojet engines is to spin the engine compressor by means of the starter. This cools the engine in the vicinity of the fire and clears out both the fuel and the fire. The rear section of the engine can withstand very high temperatures. Normally, if the fire is permitted to burn until an external power source can be connected to turn the compressor, the engine will suffer far less damage than would be caused by spraying a corrosive chemical, such as Foamite, into the engine exhaust pipe. Once this latter method is used, the engine is sent to be overhauled. If CO_2 is used to smother a fire, the engine may be severely damaged. The greatest damage to the engine by the use of CO_2 might possibly be thermal shock or seizure due to contractions. Most engine manufacturers recommend using chemicals to fight an internal fire only as a last resort. Should a fire occur while a starting attempt is being made, first turn off everything except the starter itself. Then, keep the compressor turning until the fire is out.

Internal fires may occur immediately after engine shutdown and are usually the result of a dump valve which has failed to dump (spilling manifold fuel into the engine instead). They may also be caused by a severe internal engine oil leak. It is a good practice to inspect the engine exhaust pipe for evidence of fire after each engine shutdown and to check the EGT indicator at the same time for this purpose. Should an internal fire occur, connect a power source for the engine starter as quickly as possible and rotate the compressor until all evidence of fire has disappreared.

Exercises (486):

1. How would you stop an internal ground engine fire in a turbojet engine?

2. What is the greatest damage that can be done to the engine when CO_2 is used to stop internal ground engine fires?

3. What action should be taken if an internal ground engine fire occurs while a starting attempt is being made?

487. Tell how to recognize a worker suffering from an "overdose" of noise and name the most effective ear protection equipment used to reduce noise levels.

Noise Injury Symptoms. A person who has received an "overdose" of noise may show several symptoms of sickness or injury. The affected person may have pain, a feeling of fullness, ringing or burning of the ears, sometimes dizziness, impairment of mental concentration, and occasionally nausea, vomiting, or weakness of the knees. When any of these symptoms appear, take the affected person from the noise area immediately and have him or her examined by a medical officer.

Ear Protection Devices. You can obtain protection against noise hazards by using earplugs, muffs, or helmets (fig. 5-1); selected aircraft runup areas; noise-suppression devices; and other precautions. Ear protective devices can be obtained through the base hospital and will satisfactorily protect you against most level exposures presently in the Air Force, when worn in certain combinations. Generally speaking, the earplug is most frequently worn because it provides practical protection for the most common exposures. Ear muffs or headsets, when worn in conjunction with earplugs, provide increased protection against higher noise level exposures.

Exercises (487):

1. How could you tell if an airman working at the test cell received an "overdose" of noise?

2. What combination of ear protection devices provide the greatest protection?

5-2. Preparatory and Postrun Procedures

When you prepare to operate an engine at the test cell, do not go immediately to the test cell control room and start the engine. There are a number of important steps necessary to prepare the test cell for engine test. These steps insure the safety of equipment as well as protection for the mechanic. Also, after each engine test, you should perform certain checks to assure the complete serviceability of the engine.

488. State what is likely to happen to an engine that ingests foreign objects and specify the two times an engine is checked for foreign objects at the test cell facility.

Foreign Object Damage. One of the major problems encountered in the operation of a jet engine undergoing test is FOD. According to AFR 66–33, Preventing Foreign Object Damage (FOD) to Aircraft, Missles, or Drones, FOD is the result of the ingestion of foreign materials into the engine causing damage to the stators and/or rotors of either the compressor or turbine sections. This excludes damage caused by internal engine part failures. Any FOD damage requires expensive repair or replacement of parts or even a new engine.

Studies conducted by the Air Force have shown that FOD is excessively expensive. While the cost of natural causes, ingestion of rocks and ice formations has declined. Because

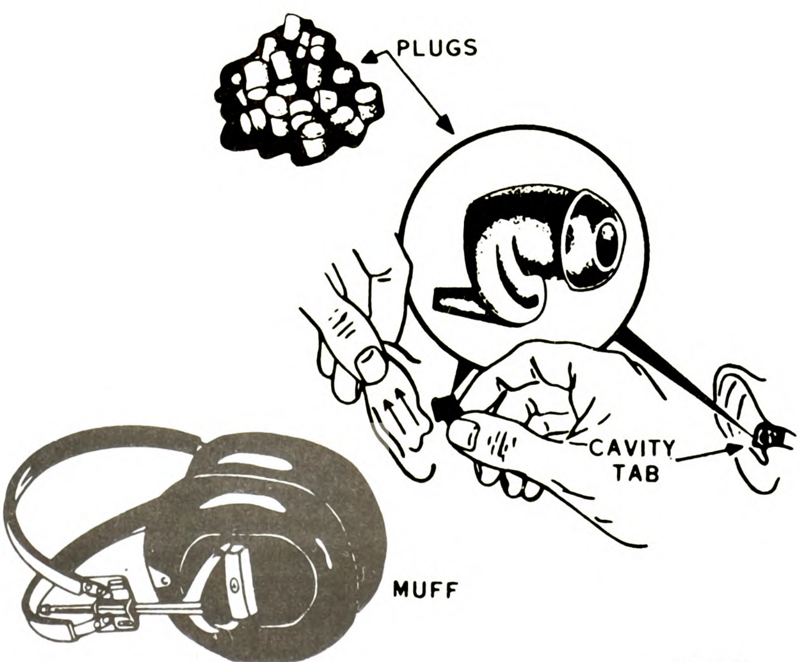


Figure 5–1. Ear defenders.

of carelessness, misplacement of tools, rags, pencils, and security badges, the cost has greatly increased.

Prior to engine operation at your test facility, inspect the engine intake for foreign objects. It is also beneficial to check the bleed valve ports and turbine area for possible FOD. This could prevent your making a performance or functional check only to later discover that the engine had previously encountered FOD, rendering it unserviceable. The prerun check does not preclude a post operational check. The possibility of FOD is ever present and has no respect of persons or equipment.

Exercises (488):

1. What happens when an engine ingests foreign objects?

2. When do you inspect an engine for FOD at a test facility?

489. State why you should check engine forms before you test run an engine and evaluate a given situation to decide whether the engine is operable or nonoperable.

Engine Forms. Always make it a policy to check the status of the engine before any testing. This check should tell you if any condition exists that may have been unknown to you. Always make it a prerequisite to check the engine forms before starting the engine. The forms are equally important as the engine itself. Without them, you would not know the true status of the engine. You may get the status verbally, but do not forget verbal statements can be misquoted as well as misunderstood. Also, memories are sometimes very short. It may be impossible for you to retain by memory all the engine problems that you may encounter in a single day. The engine forms provide a record for future reference to help preclude any error of memory, misinterpretation, or misunderstanding of speech.

When an engine arrives at the test facility, it should be completely assembled with applicable forms attached. Because of your isolation from any source of replacement engine parts and adequate special tools, all parts should be properly installed with the specified torque applied. In final analysis, once an engine arrives for test run, it should be in an operable condition with all known discrepancies corrected.

Exercises (489):

1. Why should engine forms be checked just before a test run?

2. On arrival for a test run, the engine forms indicate the main fuel control was replaced. Your inspection confirms what the forms indicate; however, you notice the fuel bypass line is attached only to the fuel pump. Can the engine be test run? Explain.

490. State how to check the throttle linkage prior to a test run and what should be checked if the engine is run in the QEC configuration.

Throttle Linkage. Throughout this text we have made comments such as, "this is an important procedure," "This is the most significant step," or, "don't forget this portion." All these are doubtless true, but take special note of the throttle linkage inspection before a test run. A tremendous amount of man hours has been expended on a costly piece of equipment. If an unsatisfactory start occurs, you must move the throttle to the OFF position. With an insecure throttle linkage, you could possibly get an abnormally high EGT because you are not able to discontinue the fuel supply to the engine. Another factor to be aware of is misaligned throttle linkage. The result could be engine overspeed, causing extensive engine damage. All this has been mentioned to emphasize the importance of checking the throttle linkage for full and free travel over the entire control range and proper security of all linkage and attaching hardware.

QEC Check. Immediately prior to an engine test run, check the QEC kit parts for loose nuts, bolts, safety wire, tools, or any other material which could cause FOD to the engine. Also, check the oil supply for the CSD and the hydraulic pumps. Always service these systems, if necessary, with the proper type and grade of oil which is given in the applicable publications. If it has not been previously accomplished, install the bellmouth, inlet screen, test engine tailpipe, and fan discharge ducts.

Exercises (490):

1. How do you check the throttle linkage prior to an engine test run?

2. What checks are made prior to an engine test run with the QEC kit installed?

491. Specify how you perform an ignition check, list the standard steps of a prestart check, and the steps involved in a leak check.

Ignition Check. To check the engine ignition system, apply electrical power to the system by pressing the ignition test switch. Have the ground observer listen beside the combustion section of the engine for the igniter plug firing. You should hear a distinct and steady snapping sound. If the snapping sound is intermittent or if no sound is heard,

troubleshoot the system as outlined in applicable publications.

Prestart Check. A prestart check can differ among types and models of engines. Keep this in mind and always check the specific TO for each individual engine. There are, some standard jobs to perform on all engines to be tested. It is of the utmost importance that you check the engine oil supply to insure it is the proper grade and quantity. Do not mix different grades of oil. Always refer to the applicable engine publication for type and grade of oil to be used.

Inspect the engine intake for foreign objects and the compressor for freedom of rotation. Connect pertinent lines and leads. Check the security of the engine in its mounts and the engine dolly for proper installation. Inspect all tanks for proper contents and servicing.

Leak Check. Leaks found should be recorded on the logsheet and if possible corrected before further engine operation. With the main fuel inlet line connected, turn the starter switch to ON and observe the tachometer until the engine reaches the specified fuel manifold pressure or fuel flow indication. Do not exceed starter limitation during this period. Close the throttle, being sure that fuel manifold pressure or fuel flow drops. Allow the starter to continue motoring the engine to clear residual fuel. Place the starter switch to OFF. During the coast-down, observers should carefully check for leaks. Failure to detect and correct leaks may result in an external fire which could cause extensive damage to the engine and test cell equipment, as well as possible injuury to the crew.

Exercises (491):

1. How do you perform an ignition check at a test facility?

2. What are the standard steps of a prestart check?

3. Tell how to perform a leak check.

492. List precautions necessary immediately after shutdown of the engine and the required checks of the engine and test stand.

Postrun Procedures. After you have allowed the engine to operate at cooling speed for five minutes, you scavenge the oil and rapidly move the throttle to the OFF position. There are certain precautions necessary for self-preservation and equipment protection. Be careful of the exhaust section from the standpoint of the excessive heat. If you must work in this area immediately, use asbestos gloves. Also, beware of a relight from unburned fuel that may have accumulated after shutdown. This indicates danger at the intake as well as the exhaust. If you notice any fuel in the engine after shutdown, motor the engine to rid it of this potential danger. This will also eliminate the possibility of unwanted fire that would not only damage the engine but the test facility as well.

Engine Checks. After necessary precautionary measures have been taken, you should carefully check the engine for any leaks that possibly developed on shutdown. Too, it is beneficial to check security of engine components that may have vibrated loose during the test run. If you are unable to make corrective action for leaks or component security, be sure to note the fact on the appropriate engine form.

Test Stand Checks. Turn off boost pump, fuel valves, hydraulic pump, air compressor, and heat exchanger. Place all power switchs to OFF. Discontinue the air-conditioning system and open all AC and DC switches including circuit breakers. To help preclude test facility downtime, make a thorough inspection of the thrust bed and frame. Repair frayed leads and worn hoses if necessary. Servicing the fuel, oil, and hydraulic system will speed the next engine test.

Exercises (492):

1. What are the precautions necessary immediately after engine shutdown?

2. What engine checks should you make after shutdown?

3. What are the test stand checks at the completion of a test run?

5-3. Test Log Entries

As test facility supervisor, you will be responsible for appropriate entries on the test log sheet. When you fill out a test log, complete each entry carefully to make the log sheet accurate and useful. It becomes a part of the engine historical data, so legibility is a requirement.

493. State the purpose of the AFTO Form 340 and list some general entries on the test log sheet.

AFTO Form 340. The AFTO Form 340, B–52 and EC/KC/RC–135 Power Package Test Log, (fig. 5-2) is not the only test log sheet used in the Air Force. The AFTO Forms 13, 35, 42, 96, 113 or 132 may be used for other types or models of engines. (Some of these forms are designed specifically for use during a test cell run while others such as the AFTO Form 132 is designed for use when the engine is installed on the aircraft. These forms are used to record data observed during the production test run of turbojet engines. They provide a record of the engine test for future reference and serve as documentary proof that the engine was subjected to the prescribed test procedures. Again, we must emphasize that the data must be complete, accurate, neat, and legible. All information entered on these forms serves as a basis for engine operation analysis.)

B-52 AND EC/KC/RC-135 POWER PACKAGE TEST LOG

ORGANIZATION	DATE 26 OCT. 67	TYPE OF TEST RUN TYPE 2	AMBIENT TEMP 65°F	TARGET VALUES	PT7	EPR	PT7	EPR	PT7	EPR	TARGET VALUES	PT7	EPR	PT7	EPR	PT7	EPR
ENGINE SERIAL NUMBER 600521	ENGINE TIME 3160	DATA PLATE %RPM 95.94	BAROMETRIC PRESS 28.641	DRY TRIM	66.9	2.39					SIMULATED WET TRIM						
ENGINE TYPE-MODEL SERIES J57-F-29WA	POSITION CONFIG #8	BIAS %RPM CORR		PART THRUST DRY TRIM							ACCELERATION TARGET	66.8					
		ADJ DATA PLATE %RPM		DRY SET							DETERIORATION CHECK SET						
				WET TRIM	72.9	2.55					EGT SPREAD CHECK SET						

COLUMN NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
TIME OF DAY (SHUTDOWN 1603)	1500	1501	1517	1519	1520	1522	1525	1527	1532	1535	1537	1538	1543	1549	1547	1550	1552	1554	1556	155[illegible]
DURATION MINUTES	1	16	2	1	2	3	2	5	3	2	1	5	1	3	3	2	2	2	2	5
	START	AFTER START	SHUT DOWN	START 2	IDLE	DRY MRT	DRY MRT	IDLE	MRT	MRT	WET	IDLE		MRT	MRT					IDLE
POWER LEVER SETTING									OIL	COOLING										
RPM CORR FOR INST ERROR — N1 %RPM						101.8	101.8		CHECK.					98.7		96.3	94.3	92.8	91.9	
N2 %RPM					63.4	97.7	97.7				97.4			96.3		95.0	93.7	92.0	92.2	63.9
PT7 - INCHES HG						66.7	67.0		66.9	67.0	72.9			67.0		64.0	61.0	59.0	57.4	
EPR																				
EXHAUST GAS TEMP °F					520	1095	1090	520	1090	1090	1135			1020		965	895	835	785	518
FUEL — INLET BOOST PRESS					25	17	17				16			17		17	17	17	17	25.5
FUEL — FLOW - TEST STAND					850	7020	7035				9400			7025		6925	5880	5520	5170	850
FUEL — FLOW - ENGINE					840	6810	6825				9120			6805		6230	5705	5355	4915	840
FUEL — ENGINE PUMP "OUT" PRESS	270			275		600	600				760			600						
OIL — PRESSURE - DIRECT					44.3	45.1	45.3							45.2		45.2	45.2	45.1	44.9	44.2
OIL — PRESSURE - TRANSMITTER					44.0	44.8	45.0							45.0		45.0	45.0	44.9	44.8	44.1
OIL — ENG OIL "IN" TEMP °F			202		203	225	225		224	225				225		220	215	210	200	200
OIL — COOLER "IN" TEMP °C									106											
OIL — COOLER "OUT" TEMP °C										72										
OIL — SCAVENGE OIL PRESS	14				30	31	31							31		31	31	31	31	30
WATER PRESSURE																				
BREATHER PRESS - INCHES HG					0.1	0.6	0.6			0.6				0.6		0.6	0.5	0.5	0.5	0.1
VIBRATION — INLET CASE - MILS					0.5	3.5	3.6			3.3				3.6		3.3	3.0	2.8	3.1	0.5
VIBRATION — DIFFUSER CASE - MILS					0.2	0.7	0.6			1.0				0.6		0.5	0.5	0.6	0.4	0.2
VIBRATION — TURBINE CASE - MILS					1.8	2.7	2.4			2.8				2.5		2.4	2.3	1.9	2.0	1.7
VIBRATION — ACC DR ADAPTER - MILS					0.4	0.9	0.9			1.4				0.8		0.9	0.8	0.9	0.8	0.9
PRESSURE — PS3																				
PRESSURE — PS4 PSI						137.5	137.5							137.5		135.5	134.0	133.5	132.0	
PRESSURE — PCP PSI						56.7	58.0							58.0		56.5	55.0	54.2	51.6	
16TH STAGE AIR SAMPLING CHK.						OK														
GROUND FLAP ACTUATION								OK												
WATER INJECTION TUBING LEAK CHECK											OK									

Column 2: ENGINE INTEGRITY CHECK (SEE DATA BELOW)
Column 8: ENGINE COOLING PERIOD
Column 12: ENGINE COOLING PERIOD
Column 13: ACCELERATION CHECK (SEE DATA BELOW)
Column 15: ANTI-ICING SYSTEM CHECK (SEE DATA BELOW)

SPECIAL CHECKS

ENGINE START CHECKS

START NUMBER		1	2	3
EGT OBS	°F	720	700	
FUEL FLOW - PEAK	PPH	1150	1200	
STARTER CUT OUT	%RPM	48	48	
STARTING TIME TO IDLE	SEC	27	27	

ENGINE INTEGRITY CHECKS

PEAK VIBRATION	MILS	%RPM
INLET CASE	3.7	96
DIFFUSER CASE	0.7	95
TURBINE CASE	2.5	94
ACC DR ADAPTER	0.9	94
PEAK BREATHER PRESSURE - IN HG		1.2
ALT SIMULATION CHECK		OK
MAX BREATHER PRESSURE - IN HG		6.5
P & D VALVE LEAKAGE CHECK		OK
AIR LEAKAGE CHECK		OK
FUEL ~~OIL HYDRAULIC~~ LEAK CHECK		OK
HYDRAULIC PUMP CHECK		
%RPM		
PUMP INLET PRESSURE		
PUMP OUTPUT PRESSURE		
PUMP OUTPUT FLOW GPM		
PUMP CASE DRAIN FLOW GPM		

GENERATOR CHECKS

RPM			
0 KW LOAD - DIFF VOLT CHECK			
FREQUENCY	CPS		
VOLTAGE	VOLTS		
ϕ1 - ϕ2	VOLTS		
ϕ2 - ϕ3	VOLTS		
ϕ3 - ϕ1	VOLTS		
ϕ1 - N	VOLTS		
ϕ2 - N	VOLTS		
ϕ3 - N	VOLTS		
3 KW LOAD - DCP CHECK			
ϕA	VOLTS		
ϕB	VOLTS		
ϕC	VOLTS		
9 KW LOAD - DIFF VOLT CHECK			
FREQUENCY	CPS		
VOLTAGE	VOLTS		
COMPRESSOR BLEED VALVE CHECK		CLOSE	OPEN
LEFT - ~~PT7 EPR N1 RPM~~ N_1% RPM		83.6	84.7
RIGHT - ~~PT7 EPR N1 RPM~~ N_1% RPM		93.0	92.2

ANTI-ICING SYSTEM CHECK

RECORDED AT	PRE-START	MRT	MRT 1 MIN	MRT 3 MIN
VALVE POSITION	CLOSED	CLOSED	OPEN	OPEN
L H TEMP °C	31	40	180	195
R H TEMP °C	32	40	185	195

EGT SPREAD CHECK

THROTTLE POSITION	PART THRUST	MRT
1 THERMOCOUPLE °F		1055
2 THERMOCOUPLE °F		1130
3 THERMOCOUPLE °F		1085
4 THERMOCOUPLE °F		1115
5 THERMOCOUPLE °F		
6 THERMOCOUPLE °F		
7 THERMOCOUPLE °F		
8 THERMOCOUPLE °F		
EGT AVERAGE		

ACCELERATION CHECK

TIME - IDLE TO TARGET PT7 EPR	SEC	10
EGT MAX OBS	°F	1125
BREATHER PRESSURE	IN HG	2.9
OIL PRESSURE - DIRECT		45
OIL PRESSURE - TRANSMITTER		44
N1 COAST DOWN TIME	SEC	115
N2 COAST DOWN TIME	SEC	98

MISCELLANEOUS CHECKS DATA

TEST DATA EVALUATION

N2 %RPM COMPARISON ☐ ACCEPT ☐ REJECT		
ADJUSTED DATA PLATE %RPM		
OBS MRT PART THRUST N2 %RPM		
%RPM OVER/UNDER CORR DATA PLATE		
EGT SPREAD CHECK ☒ ACCEPT ☐ REJECT		
HIGH THERMOCOUPLE NO.	°F	1130
LOW THERMOCOUPLE NO.	°F	1055
TEMPERATURE SPREAD		75
OIL PRESSURE EVALUATION ☒ ACCEPT ☐ REJECT		
CORRECTED DIRECT OIL PRESSURE - MRT		45.0
TRANSMITTED OIL PRESSURE - MRT		45.0
PSI DIFFERENCE - DIRECT VS TRANSMITTED		0
OIL COOLING SYSTEM CHECK ☒ ACCEPT ☐ REJECT		
OIL COOLER "IN" TEMP - MRT	°C	106
OIL COOLER "OUT" TEMP - MRT	°C	72
TEMP DROP ACROSS COOLER	°C	34
OIL CONSUMPTION RATE ☒ ACCEPT ☐ REJECT		
QTY OF OIL SERVICED - POSTRUN	FL OZ	0
TEST RUN DURATION	MINUTES	63
OIL CONSUMPTION RATE		0

ENGINE DETERIORATION CHECK ☐ ACCEPT ☐ REJECT	
OBS PT7	
MAX ALLOWABLE PS3 PSIA/IN HG ABS	
CORR OBS PS3 PSIA/IN HG ABS	
PSI IN HG OVER/UNDER MAX ALLOW	

TURBINE COOLING AIR CHECK ☒ ACCEPT ☐ REJECT

CK PT NO.	OBS N2 %RPM	PCP (PSIA)	PS4 (PSIA)	PCP (PSIA) / PS4 (PSIA)
1	96.3	72.0	151.5	0.475
2	95.0	70.5	149.5	0.472
3	93.7	69.0	148.0	0.465
4	93.0	68.2	147.5	0.462
5	92.2	65.5	146.0	0.449

ANTI-ICING SYSTEM CHECK ☒ ACCEPT ☐ REJECT

VALVE POSITION MRT	L/H VALVE OFF	L/H VALVE ON 1 MIN	L/H VALVE ON 3 MIN	R/H VALVE OFF	R/H VALVE ON 1 MIN	R/H VALVE ON 3 MIN
OBS TEMP °C	40	180	195	40	185	195
PRERUN TEMP °C	31	31	31	32	32	31
TEMP INCR °C	9	149	164	8	153	164

REMARKS

OPERATION

INSPECTION

ENGINE ☒ ACCEPTED ☐ REJECTED

AFTO FORM JULY 67 340

Figure 5–2. AFTO Form 340.

General Entries. On receipt of the engine for test at your test facility, enter the engine model and serial number, the work order number, the date, the Air Force base, and the organization in the blank spaces provided at the top of the test log sheet. Check the model and serial number with the data plate on the engine. Now is a convenient time to annotate the data plate rpm.

Exercises (493):

1. What is the purpose of the AFTO Form 340?

2. List the general entries that are annotated on the test log sheet.

494. Specify the desired Pt7, compute the adjusted data plate rpm for a given N_2 speed and temperature, and tell who verifies the test log sheet's completeness and accuracy.

Test Cell Trim Check. Once you have the engine properly installed in the thrust frame and the necessary connections completed, you are ready for the performance check. If equipment is available, get the temperature and uncorrected barometric pressure at the test site. But you may use the field readings normally furnished by the control tower.

Determine target Pt7. The Pt7 reading is used to measure exhaust gas pressure in inches of mercury (Hg). By combining Pt7 with Pt2 the resulting ratio can be used to determine thrust output. Since Pt2 is fixed by atmospheric conditions, you cannot change it. However, Pt7 can be varied during trim by adjusting the fuel control.

You cannot just adjust the fuel control arbitrarily. First, you have to use a trim chart such as the one in figure 5-3. If the temperature at your test site is 68° F. and the uncorrected barometric pressure is 29.5-inches Hg, follow along the top of the chart to 68.0. Then go down that column until you reach the uncorrected barometric pressure listed on the left side of the chart. You can see that your target Pt7 at military rated thrust (MRT) is 68.7-inches Hg. If you are trimming with water injection, the target Pt7 is 74.9-inches Hg. As you can see, the chart is quick and easy to use and all errors in computation have been eliminated.

Computing bias rpm. N_2 speed of an engine is expressed in actual rpm and the percent of rpm at which it must run to produce military thrust on a standard 59° F. temperature day. This is stamped on the data plate. The fuel control is temperature biased to automatically vary N_2 speed variations from a standard day. To determine the adjusted data plate speed, refer to your pertinent technical publication for your particular engine undergoing test.

To determine a sample bias rpm again refer to figure 5-3. In the example given above, the temperature was 68° F. so go across the top of the chart to 68.0. Immediately beneath this number is the bias rpm adjustment in percent. In this example, the bias is a 0.21 percent. This figure would be added to the data plate percent rpm. On days when the temperature is below 59° F. there would be a minus in front of the bias rpm such as for 50° F. the bias is −0.22. This would be subtracted from the data plate percent rpm.

Verification. Once the test run is completed and readings annotated on the test log sheet, authentication is required. The operator signs the test log sheet and a qualified inspector

BAR. PRESS ·IN.HG											
	TEMP. F	60.0	61.0	62.0	63.0	64.0	65.0	66.0	67.0	68.0	69.0
	BIAS RPM %	0.02	0.04	0.07	0.09	0.12	0.14	0.16	0.19	0.21	0.24
	EPR MRT	2.37	2.36	2.36	2.35	2.35	2.34	2.34	2.33	2.33	2.32
	EPR WET	SEE BELOW									
29.2	MRT-PT7	69.2	69.0	68.9	68.7	68.5	68.3	68.2	68.1	68.0	67.9
	WET-PT7	74.8	74.7	74.6	74.6	74.5	74.4	74.3	74.2	74.1	74.1
	EPR WET	2.56	2.56	2.56	2.55	2.55	2.55	2.54	2.54	2.54	2.54
29.3	MRT-PT7	69.4	69.3	69.1	68.9	68.7	68.6	68.4	68.3	68.2	68.1
	WET-PT7	75.0	75.0	74.9	74.8	74.7	74.6	74.5	74.5	74.4	74.3
	EPR WET	2.56	2.56	2.56	2.55	2.55	2.55	2.54	2.54	2.54	2.54
29.4	MRT-PT7	69.7	69.5	69.3	69.1	69.0	68.8	68.7	68.6	68.4	68.3
	WET-PT7	75.3	75.2	75.1	75.0	75.0	74.9	74.8	74.7	74.6	74.5
	EPR WET	2.56	2.56	2.56	2.55	2.55	2.55	2.54	2.54	2.54	2.54
29.5	MRT-PT7	69.9	69.7	69.6	69.4	69.2	69.0	68.9	68.8	68.7	68.6
	WET-PT7	75.5	75.4	75.4	75.3	75.2	75.1	75.0	74.9	74.9	74.8
	EPR WET	2.56	2.56	2.55	2.55	2.55	2.55	2.54	2.54	2.54	2.53
29.6	MRT-PT7	70.2	70.0	69.8	69.6	69.4	69.3	69.1	69.0	68.9	68.8
	WET-PT7	75.8	75.7	75.6	75.5	75.4	75.4	75.3	75.2	75.1	75.0
	EPR WET	2.56	2.56	2.55	2.55	2.55	2.55	2.54	2.54	2.54	2.53
29.7	MRT-PT7	70.4	70.2	70.0	69.9	69.7	69.5	69.4	69.3	69.1	69.0
	WET-PT7	76.0	75.9	75.9	75.8	75.7	75.6	75.5	75.4	75.3	75.3
	EPR WET	2.56	2.56	2.55	2.55	2.55	2.55	2.54	2.54	2.54	2.53

Figure 5–3. Trim chart for J–57 engine.

also signs to verify the annotation is correct. The test log sheet is now an official engine record.

Exercises (494):

1. With a temperature of 62° F. and a barometric pressure of 29.3-inches Hg, what is the target Pt7 wet?

2. Who signs the test log sheets verifying completeness and accuracy?

3. With a temperature of 64° F. and a data plate percent rpm of 96.49, what would be the adjusted data plate percent rpm?

5-4. Adjustment of System Units

As a technician, you test run an engine for only one reason. That is to check the engine for normal operation. What is normal operation? An engine is operating normally when it is producing the required thrust within the safe operating limits as specified by the technical data applicable to it.

495. Tell why you are forbidden to make adjustments on certain engine fuel control units and what must be done if these adjustments are accidentally made.

Fuel Control. Some of the critical adjustments you encounter are the fuel control adjustments. There are numerous external adjustment screws easily accessible to you but there are only three with which you are concerned. You can make needed adjustments on the maximum trim, the wet trim, and idle rpm. Others, such as minimum flow, burner pressure sensor, pressure regulator valve, speed servo rate, maximum ratio, and burner pressure are possibly accessible but have factory seals to help deter any field adjustment. These have been preset under proper conditions to deliver proper ratios for efficient operation. Do not break the seals at the intermediate maintenance level. If you detect any breakage or suspect previous tampering, it will be necessary to forward the fuel control to the authorized depot for flow checking and resealing.

Exercises (495):

1. Why are you forbidden to make certain adjustments on a unit?

2. What is the disposition of a unit if a forbidden adjustment is made?

496. Identify the adjustments required to bring the engine oil and fuel systems back into operable ranges.

Fuel and Oil System. The efficiency of a jet engine often deteriorates as the operational hours continue to increase. A slight amount of erosion of orifices or corrosion of valves can cause the engine to develop pressures different from the normal readings prescribed in applicable technical data. This progressive deterioration does not necessarily render the part defective to the replacement stage. With a slight adjustment, the desired performance can again be obtained.

If at normal operation, you have a fuel flow indication of 8,000 pph, rpm 96 percent, and oil pressure 45 psi, you feel relatively sure that all the openings are free and the valves operating properly.

Suppose that you are operating at military power setting and have 93 percent rpm with a fuel flow of 7200 pph and oil pressure of 38 psi. Let's evaluate each of these readings and discuss what, if any, corrective measures are needed.

The fuel flow is low, as is the rpm. You have the proper position of the throttle control for military power. Since fuel flow directly influences rpm, you need to increase the fuel flow. Turn the MAX adjustment on the fuel control to get the desired fuel flow, thus increasing rpm. Be sure to monitor Pt7 and the rpm so that you do not exceed the limits specified for the particular engine with the use of applicable charts for the temperature at time of the run.

Also, the oil pressure is low. You are sure the oil pump is operating properly so the plausible cause is maladjustment of the oil pressure relief valve to tech data limits.

The preceeding information is for training only and is not to be used in lieu of technical publications pertinent to your particular engine.

Exercises (496):

1. What corrective action is required if engine rpm is 92 percent with 6300 pph fuel flow at military power setting?

2. What adjustment is made for oil pressure of 32 psi at idle?

5-5. Malfunction Analysis

To analyze a particular malfunction, you must possess a thorough knowledge of engine systems. To a degree, the systems vary from one engine type or model to another, but the fundamentals are basically the same. These fundamentals form the foundation of knowledge that is essential for proper jet engine analysis.

497. State the importance of proper engine malfunction analysis and the advantage of properly reporting the discrepancy to the worker assigned to correct the malfunction.

Analysis Data. Fortunately, beginning engine trouble is often predicted by the engine test cell instruments well in advance of any serious difficulty. Many potential problems can be quickly and economically corrected if the engine test cell readings and the engine malfunction symptoms are interpreted properly. Conversely, misinterpretation of apparent abnormal engine operation and subsequent improper corrective action may possibly cause serious problems. Two such problems are excessive use of replacement parts and undue use of overtime work hours. With the proper understanding of each engine system and its interlocking relationships, you can increase efficiency and improve results of your repair efforts.

If you detect a malfunction and realize you do not have necessary equipment, time, or accessibility at the site, proper documentation is imperative. Even if you begin the job, you may be assigned another task while another worker completes the first one. You could truthfully record high EGT, for instance, but this only indicates the system. To afford practical information such as power setting, fuel flow and rpm at the time of the malfunction encounter is much more useful for proper analysis. Note the complete facts about the discrepancy on the proper engine forms. Then there will be no doubt of the discrepancy or the conditions surrounding it.

Exercises (497):

1. Why is it important to properly diagnose engine malfunctions?

2. How can proper reporting be of value to the person correcting a malfunction?

498. Define the term "engine evaluation" and tell how thrust is expressed for variable speed engines.

Engine Performance Evaluation. When an engine arrives at your test facility, the performance evaluation process starts. You inspect the engine and annotate your findings on the test log sheet. Temperature and barometric pressure is used to arrive at the target Pt7 and corrected data plate rpm. Now that the preliminary entries are made on the test log sheet and the engine properly mounted and supporting test equipment installed, you are ready for engine operation. Progressively you gather readings from starting to running and shutdown and compare them to acceptable standards outlined in applicable technical data. By this comparison, you evaluate the engine to determine if it meets minimum standards that show it is airworthy and reliable.

Power is expressed in varying terms for various powerplants. For an automobile we think of horsepower; a tractor, drawbar horsepower; aircraft reciprocating engine, shaft horsepower; and jet engines, thrust. Some jet engines are rated at 100 percent rpm, while others are guaranteed to deliver a given amount of thrust at less than 100 percent rpm dependent upon environmental conditions. Also, the rpm varies from one engine to another. We call this type a variable speed engine. The thrust for variable speed engines is expressed as Pt7, Pt5, or engine pressure ratio (EPR). When EGT and engine speed are within acceptable limits and Pt7/Pt5/EPR are set to their target, the engine produces the manufacturer's guaranteed thrust. As a test cell technician, you are mainly interested in Pt7 or Pt5. EPR is normally used for aircraft operation, but can be used at the test cell. The engine TO provide charts that give both the EPR and exhaust pressure ratings.

Exercises (498):

1. What does the term "engine evaluation" mean?

2. How is the thrust for a variable speed engine expressed?

499. Specify the faulty component if the engine oil consumption is excessive with no external leakage and evaluate hypothetical oil consumption data.

Excessive Oil Consumption. Every jet engine model has a maximum limit set on its rate of oil consumption. If this limit is not exceeded, the engine continues to be classified as serviceable. Check your engine and aircraft technical orders to determine the exact quantity of oil that your engine is allowed to consume each hour before you decide whether the oil consumption is excessive. If you have reason to believe that an engine is consuming too much oil, make a thorough check of all the plumbing for leakage. Correct any oil leakage by installing new lines, fittings, and seals.

Several clues indicate the presence of damaged oil seals within the engine itself. For example, oil on the turbine wheel or oil smoke at or near the turbine section is a good indication that the oil seal for the aft bearing is damaged. The aircraft maintenance forms will provide a record of the amount of oil that each oil reservoir receives at the postflight inspection. By dividing the amount of oil used since the last servicing by the number of hours the engine has been operated, you can calculate the amount of oil consumed per hour. If the engine is using too much oil, take corrective action.

Use the supposition that 4 pph (approximately 1/2 gallon or 4 pints) shall be the maximum allowable amount of oil consumption. Any sudden increase in consumption in excess of 2 pints per hour shall be cause for rejection of the engine. Refer to the AFTO Form 781, Areospace Vehicle Flight Data Document, for the record of oil consumption during previous

hts. You can use this record to recognize a sudden rease in oil consumption.

ercises (499):

What part would be defective if you detect excessive oil consumption with no visible external oil leaks?

The engine was removed from an aircraft that had flown 6 hours and consumed 18 pounds of oil. This is an increase of 14 pints from the previous 6-hour mission. How much oil was used per hour in the flight and is this an acceptable consumption? Explain.

. Compute when the bleed valves should open and se and tell what you should do if they fail to operate on edule.

Bleed Valve Operation. There are various devices employed to stop compressor stalls. Some of the devices designed to relieve the engine of excess air are variable stators, bleed straps, and bleed valves. Bleed valves are used on variable speed engines. Some of the variables which can be used to determine the schedule of operation of the bleed valves are compressor inlet temperature, compressor rotor speed, compressor inlet pressure, and compressor discharge pressure. Figure 5-4 is a chart for a J-57 engine which uses a compressor rotor speed and compressor inlet temperature to determine bleed valve opening and closing.

Select a temperature, for example 75° F. at the bottom of figure 5-4. Proceed vertically to the darkened lines of the graph. The left bleed valve must close any place from 4895 to 5080 N_1 rpm as you read laterally. The right bleed valve must close in the range of 5395 to 5580 N_1 rpm. The opening schedule will be in the same range on deceleration.

To prevent acceleration and deceleration stalls during engine performance, the bleed system reduces the amount of air available to the N_2 compressor. The action provides surge-free operation throughout all engine speeds. This is

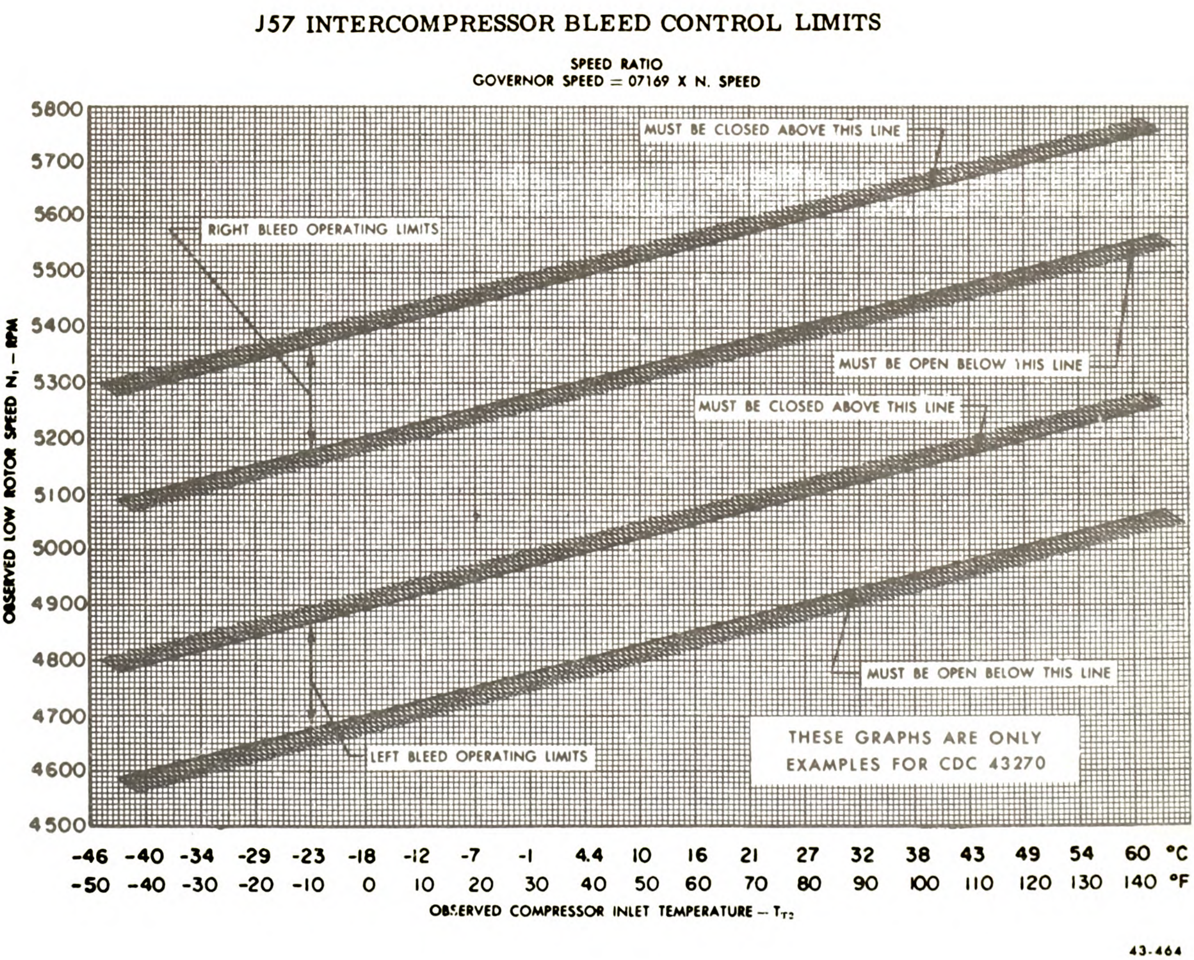


Figure 5-4. Intercompressor bleed governor limits.

done through the use of a bleed valve governor that senses the N_1 compressor speed. A signal is sent to an actuator, which in turn positions a bleed valve. The bleed valve allows excessive air to be vented overboard until the engine reaches sufficient rpm to handle all the air taken in without affecting acceleration or causing a stall. If the bleed valves don't operate correctly replace the governor and run the test again.

Exercises (500):

1. When should the bleed valves close if observed inlet temperature is 85° F.? (Use fig. 5-4.)

2. What corrective action is required if the bleed valves do not close on schedule?

Block Testing and GTCP85–180 Engine

THE PURPOSE OF this chapter is to familiarize you with principles and practices used in the operation of the GTC85-180 engine after maintenance has been completed. Since the efficient operation of this small gas turbine engine depends on your maintenance, you must be well acquainted with the testing equipment you will be using. You must know what the engine is designed to do and how it is going to do it. You should also be familiar with the inspections, starting procedures, and engine operating limitations. Finally, you should know the engine and its systems operating characteristics and specifications. This knowledge is required so that you can recognize any failure of the engine to meet operating requirements.

The procedures discussed in this chapter may be modified at any time by means of operational supplements, safety supplements, and local policies and procedures. As always, you must be sure the TOs you use are current.

6-1. Test Stand Inspection

Inspecting the test stand is one of the more important tasks that you may perform. A thorough inspection has many times disclosed a condition which could have caused a serious accident. The main purpose of inspections is to be sure that the equipment is in a safe, operable condition. Remember, many lives and dollars may be saved because your inspection disclosed a potentially dangerous situation. Accident investigations all too often reveal that the accident might have been averted had the preliminary inspection been a little more thorough.

501. State the purpose of the test stand in relation to engine operation, specify the correct inspection schedule for a test stand, and tell what an inspector looks for when inspecting selected items.

Test Stand Inspections. The trailer-mounted universal gas turbine engine test stand assembly (fig. 6-1) is commonly referred to as a test stand. It is a mobile, self-contained unit used to functionally test, checkout, and troubleshoot small gas turbine engines. Use of this test stand at intermediate and organizational levels of maintenance reduces the number of gas turbines returned to depot level maintenance prior to regularly scheduled overhaul inspections. In addition, intermediate level maintenance workers are provided with this test equipment to aid in isolation and correction of causes of malfunctions within the scope of maintenance authorized at that level.

In order to properly perform engine malfunction analysis, maintenance of the test stand is essential. This maintenance consists of periodic inspections, lubrication, and replacement of defective test stand parts. Always refer to the applicable technical manual prior to replacement of any of these parts.

The periodic inspections on the test stand will be accomplished on a regular calendar interval. The interval is determined by the number of operating hours each month. An estimate of the average operating hours per month will be determined by closely monitoring the test stand use for a period of at least 60 days. Using the monthly average, you then can obtain the calendar inspection interval using a chart such as the one below:

Schedule	*Estimated Average Operating Hours Per Month*	*Calendar Inspection Interval*
A	25	180 days
B	50	120 days
C	100	60 days
D	200	30 days

In determining the inspection schedule, use the hour increment which is closet to the average operating hours.

The periodic inspection will consist of, but not limited to, the following inspections and procedures. Check your technical order prior to the start of any inspection.

a. Remove the oil spillage drains hoses and their attaching parts and drain the oil drain cans. Replace cans and reinstall the drains hoses and attaching parts.

b. Remove, inspect, and replace the fuel filter. The filter is located under the console panel.

c. Inspect the electrolyte in the batteries for proper fluid level and check for low or dead cells. If you find a dead cell, replace the battery.

d. Remove the cover for the battery compartment and inspect the interior of the battery compartment and the battery attaching parts for evidence of rust or corrosion. Remove the rust or corrosion with a wire brush. Inspect the asbestos cover for excessive soakage of oil.

e. Remove the exhaust duct assembly from the front of the storage compartment. Check the thermocouple in the exhaust duct assembly for accuracy, and replace the thermocouple if it is defective. Examine the flanges of the exhaust duct for nicks or other physical damage.

f. Visually inspect all fuel, oil, and hydraulic lines and fittings for evidence of leaks or damage.

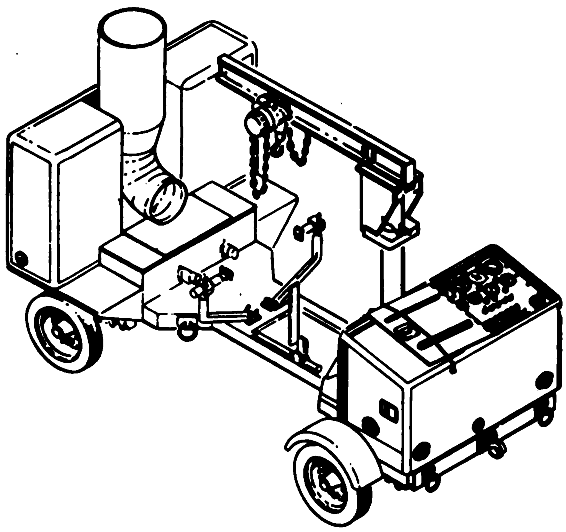


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Figure 6-1. Trailer-mounted universal gas turbine engine test stand.

g. Visually inspect all electrical conduit, connectors, receptacles, wiring and instrumentation for evidence of loose, burned, or corroded connections. Inspect insulation for evidence of damage.

h. Inspect the test stand for loose nuts, bolts, or rivets. Replace loose rivets and missing attaching parts. Tighten screws, nuts, and bolts.

i. Inspect the hinges and catches of the access doors for evidence of damage. Drill out rivets or remove attaching parts and replace defective parts.

j. Clean all metallic portions of the test stand, using a clean cloth moistened with PD–680. Remember to use this solvent only in a well-ventilated area. Avoid breathing the fumes and keep it away from flames.

k. Check the paint for evidence of damage. Repaint areas of damage to technical order specifications.

l. Successively jack up each corner of the test stand by using a hydraulic jack and rotate the wheels. Check the wheels for security of attachment, excessive noise during rotation, tire wear, and nails or other objects in the tires. Remove each wheel and inspect the condition of the brake linings, drums, and actuating mechanisms. Check the tire pressures to insure that they are properly inflated (check the TO for this pressure).

m. Drain the fuel tank and check the drained fuel for evidence of contamination. When the fuel tank is empty, check the indication on the fuel gage. If the gage does not indicate an empty reading, bend the arm of the float to provide the correct indication. If the drained fuel is not contaminated, it can be strained and poured back into the fuel tank. When the fuel tank is full, the fuel gage may indicate slightly higher than the full mark.

n. Lubricate the test stand. Refer to the proper technical order to locate the lubrication points.

Exercises (501):

1. What is the purpose of the test stand in relation to engine operation?

2. The test stand in your unit has to be placed on an inspection schedule. During a 60-day monitor of test stand use you find that there were 143 hours of operation. What inspection schedule would you use? Explain your answer.

3. What would you be looking for when you inspect the following items?
   a. Batteries.

   b. Exhaust duct assembly.

   c. Hinges and catches of access panels.

502. Specify preoperation and servicing of the test stand and state the type and quantity of oil for the tanks.

Preoperation Inspection and Servicing of the Test Stand. A preoperation inspection and servicing of the test stand and its related system is necessary. For example, if an operating engine shuts down due to lack of fuel, both the fuel pump and control could be damaged since fuel is used for lubrication of these units. When you prepare to operate an engine, you do not go immediately to the console and start the engine. There are some things you must do first.

Service the fuel tank with 40 gallons of fuel conforming to military specification MIL–F–5624, JP–4. Be sure that the fuel gage indicates the proper quantity. The test stand has two oil tanks, each of which holds 2.45 gallons of oil. The right-hand oil tank is serviced with MIL–L–7808 oil, and the left-hand oil tank is serviced with oil conforming to military specification MIL–0–6081, grade 1010. Inspect the test stand for leaks and general condition. Any discrepancies must be corrected before operation. The front, rear, left, and right areas of the test stand are viewed with the operator located at the console, looking forward toward the exhaust pipe and drawbar. Check the battery for proper fluid level and install the battery cables.

Exercises (502):

1. What could happen if the engine shuts down because of lack of fuel?

2. How do you recognize the left and right sides of the test stand?

3. What are the oil tanks serviced with?

4. What are the oil tank capacities?

6-2. Engine and Equipment Installation

The GTCP85–180 test stand consists essentially of a welded chassis supported by rigid front and rear axles with independent spring suspension. A console located at the rear section of the test stand accommodates a fuel supply tank, two lubricating oil supply tanks, a complete engine analyzer test panel, and associated plumbing and electrical circuitry. A hoist mounted on the chassis is used for installation and unloading of units under test. A front storage cabinet, divided into two separate compartments, provides storage space for required accessories, adapters, electrical cabling, wiring harnesses, and portable test equipment. An exhaust pipe, located between the front storage cabinet sections, reduces noise and directs exhaust gas fumes away from test workers. A drawbar is attached to the front steerable axle to move and position the test stand.

503. Specify where to find information on adapter kits for a particular engine, name what is used to move the engine, locate various connecting and reference points, and state the significant precaution for connecting the starter harness.

Preparation for Engine Operation. Certain accessories, mounting equipment, and adapters are stored in the front storage cabinet of the test stand. These items are used to install and connect the test engine to the test stand. In some cases, certain customer furnished equipment is also required. In addition to the test stand and customer furnished equipment, various adapter kits are required to install and interconnect various engines in the test stand prior to testing the engine. Always refer to the intermediate maintenance TO for the adapter kit that is required for the small gas turbine engine that you are testing.

Engine installation in the test stand. Refer to foldout 1, figure 1, for this portion of this text. (We will give you the item numbers that correspond with this foldout unless otherwise specified.) Normally, the engine will be on a maintenance stand when it is ready for testing. Then it must be transferred to the test stand, item 20. Two mounts are provided for this engine installation. Install the solid side mount and the expansion side mount provided in the adapter kit on the engine. The main side mounts, item 27, are installed on the test stand at the position marked 85–12 (not shown on FO 1). The pins are then removed from the main side mount, and the vee-clamp assemblies, item 28, are placed in the upper position. Replace the pins in the main side mounts. Remove the eyebolts, item 29, and open the vee-clamp assemblies. Move the slide mount, item 21, to the position marked on the deck plate as 85–12. Install the engine third point support, item 24, stored in the test stand storage cabinet on the slide mount, item 21, and secure with pins, item 23. Connect a sling to the engine and attach the unit hoisting hook to the bracket, item 6. The hoisting boom, item 17, pivots. Carefully lift the engine from the maintenance stand and guide the engine into place on the test stand. Align the engine side mounts, items 30, to fit into the vee-clamp assembly and close these clamps. Secure the eyebolts. Remove the engine transfer sling and swing the engine boom aside. The exhaust duct, item 32, can now be installed and secured with a clamp furnished with the test stand. You now have the engine installed and secured in the test stand.

Test equipment hookup. You are now ready to connect the engine to the test stand. The thermocouple lead, item 1, located in the exhaust duct, is connected to the thermocouple lead receptacle, item 31, which is located in the battery compartment, item 34. Connect the end of the adapter cable, item 36, from the adapter kit and connect it to the adapter cable receptacle, item 35, on the test stand frame, item 37. Refer to the intermediate maintenance technical order special tool group section to obtain the proper adapter cable for the engine being tested. An identification plate from the adapter kit is placed over lights 18 through 30, foldout 1, figure 2, on the test stand analyzer panel. The adapter cable, item 36, is connected to the control box connectors, items 3 and 8, and relay (HR–3) connector, item 26, and the low oil pressure sequencing switch, item 58. Install the adapter cable, item 36, containing the oil temperature bulb to the oil pump assembly, item 16. Disconnect the control air line, item 51, at the fuel pump and control unit, item 53. Install a tee, item 57, between the line and the fuel pump and control unit. Connect the control air pressure sensing hose assembly, item 43, between the tee and the control air connection, item 40, on the test stand. Connect the oil pressure sensing hose assembly, item 12, between the tee, item 11, and the oil pressure connection, item 38, on the test stand. Remove the plug from the fuel pressure sensing port, item 54, on the fuel pump and control unit and install a union, item 52. Connect the fuel pressure sensing hose assembly, item 42, between the union and the fuel pressure connectin, item 39, on the test stand. Remove the plug from the top of the accessory gear case port, item 15, and install a pressure sensing tap, item 14, consisting of a suitable tee and two reducer bushings. Reinstall the plug in the tee. Connect the accessory case pressure hose assembly, item 13, between the tap and the accessory case pressure connection, item 41, on the test stand. Connect the flat terminals of the starter harness, item 25, to the starter motor, item 10, observing polarity marked on the terminals and harness. Connect the starter harness, item 25, to the starter harness receptacle, item 33. Install the 2–015519S11–8D coupling (component of the test stand) on the MIL–L–7808 oil return connection, item 48, and attach the 282105–9 oil return hose assembly, item 47, to the coupling. Attach the other end of the hose assembly to the oil fitting, item 50, on the outlet. Install the 2–015519S11–12D coupling (component of the test stand) on the MIL–L7808

oil-to-engine connection, item 46, and attach the 282105–10 oil-to-engine hose assembly, item 22, to the coupling. Attach the other end of the hose assembly to the inlet on the oil pump assembly, item 16. A coupling is installed on the oil vent connection, item 44. Attach the oil vent hose assembly, item 5, to the coupling. Attach the other end of the hose assembly to the engine oil vent connection, item 4. Install a coupling on the fuel outlet connection, item 45, and attach the fuel supply hose assembly, item 49, to the coupling. The other end of the hose assembly is attached to the fuel inlet, item 55, on the fuel pump and control unit, item 53. Install the duct assembly, item 60, and a gasket on the air shutoff valve, item 2, with a clamp, item 59. Install the valve, item 62, and a gasket on the duct assembly, item 60, with a clamp, item 61. Attach the valve control box assembly, item 18, to valve, item 62, and connect the plugs of the control box assembly to jacks, foldout 1, figure 2, items 50 and 51. Position the switch on the valve control box assembly, item 18, to open the valve, item 62. Energize the switch, foldout 1, figure 2, item 52, on the engine analyzer panel to motor the air shutoff valve, item 2. Remove the plugs from the jacks.

This completes the engine to test cell connections. Check all electrical, hydraulic, and pneumatic connections for security of attachment.

Exercises (503):

1. Where could you locate information on adapter kits for the small gas turbine engine assigned to your station?

2. What device is used to transfer the engine from the maintenance stand to the test stand?

3. What reference point is used for the main side mount during engine installation?

4. What are the connectors on the adapter cable connected to?

5. Where is the accessory gear case pressure extracted?

6. What caution is taken when connecting the starter harness?

7. In what two locations is the fuel hose attached?

504. Define the term "loaded condition" and specify when to take vibration measurements on a test run and when you may exceed TO vibration limits.

Vibration Check. The test stand has the capability of performing a complete preoverhaul test of a unit. Panel mounted instruments, foldout 1, figure 1, item 19, was blown up on foldout 1, figure 2, provided in the test stand monitors air and liquid pressures, exhaust gas and unit oil temperatures, shaft speed, and electrical frequency, voltage, and current. No provision is made to sense vibration. Vibration levels are checked whenever bearings, seals or engine internal components are replaced.

A detailed explanation of a vibration analyzer was given previously in this volume. The major difference here is the setup procedure. Only one vibration pickup is used to monitor vibration of the engine. Remove the bracket, foldout 1, figure 1, item 6, located at the top of the compressor housing pad. A mount, figure 6-2, is installed in this position and the vibration pickup is installed on the mount. Attach the vibration meter to the pickup and measure the vibration levels under two engine operating conditions, no-load governed speed, and loaded condition.

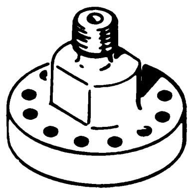
No-load governed speed. For a no-load governed speed, start the engine and allow it to accelerate under manual control until it reaches its governed speed. During acceleration and deceleration, transient vibration may exceed the prescribed technical order limits.

Loaded condition. A loaded condition means that the engine is under a bleed air condition. The switch on the valve control box assembly, foldout 1, figure 1, item 18, is placed in the CLOSED position. The load switch, foldout 1, figure 2, item 31, is actuated to open the air shutoff valve. Slowly open the valve to apply a bleed load to the engine. The vibration which occurs at this time shall not exceed the prescribed technical order limits. Actuate the stop switch, foldout 1, figure 2, item 13, to shut down the engine.

After this check is made, remove the vibration meter, pickup, and mount and replace the bracket.

Exercises (504):

1. When is vibration measured on a test run?



43-466

Figure 6–2. Vibration pickup mount.

2. When are vibration limits allowed to exceed prescribed limits?

3. Define the term "loaded condition."

4. Intermediate maintenance is ready to test a small gas turbine engine. The records indicate that a turbine wheel was replaced. In addition to the normal checks on a test run, what other check is to be completed?

6-3. Preoperational and Operational Checks

Preoperational and operational checks are performed on all engines that are to be tested. You should be sure that you know what is to be done before attempting to make an engine test. The following questions evaluate your preparedness for performing an engine test:

- Do you have a job plan for each phase of the engine test?
- What safety precautions are to be observed when testing the engine?
- Do you and your workers know the starting, emergency, and shutdown procedures?

Have a plan, before you operate the engine, that will enable you to make a thorough but brief performance check.

With the test engine in place on the test stand and all cabling and hose assemblies attached, the test stand serves as a functional unit and provides test personnel with performance data during a test. There should be certain customer furnished accessories, in addition to the equipment provided with the test stand, in order to test all units within the capability of the test stand. Starter power and switching circuits are incorporated in the test stand, eliminating any requirement for external power.

505. State the purpose of a preoperational inspection, distinguish between the two test leads, and associate various test items with the test stand analyzer jacks through which they are checked.

A preoperation inspection is needed to insure that the testing equipment and engine components are functioning properly. The testing equipment should be hooked up, activated, and ready for use. Make this inspection after the engine is installed in the test stand and just before engine operation.

Initial Setup of Multimeter and Test Stand Analyzer Panel. The test stand ahalyzer panel is discussed, in part, as each phase of engine operation is discussed. Also, in order to prevent repetition, foldout 1, figure 2, is used throughout this objective. (Refer to this foldout for the item numbers given after the components in this portion of the text.) For example, the manual speed control valve, item 12, is placed in the CLOSED position. All the switches on the test stand analyzer should also be in the CLOSED position.

A multimeter and test leads are supplied with the test stand to perform the checks discussed in this objective. This unit is stored in the test stand in a front storage compartment. Insert the red test lead into the terminal indicated +10A on the multimeter and plug the other end of the red test lead into the +24V DC jack, item 50, of the test stand analyzer panel. This lead remains installed in this position throughout the static test. Place the left hand switch of the multimeter in the DC position and set the range selector switch at 10 amps. Insert the black lead into the terminal indicated as −10A on the multimeter. Use the other end of the black lead to isolate specific components. A word of caution is in order at this point. You may see a momentary peak indication on the multimeter immediately after certain circuits are energized. Make certain that the meter needle does not remain "pegged." If this happens, remove the black test lead from the meter. Shut off the system power on the test stand analyzer panel by placing the master switch, item 14, in the OFF position.

Static Check of Engine Components. Whatever checks you are making, always beware of what someone has labeled the tester law. The value of test equipment is directly proportional to the operator's knowledge of the equipment on which it is being used. That is, if the person using the analyzer knows the operation and interaction of the various components of the gas turbine unit, the analyzer can provide him the information needed to locate all of the significant troubles. If the operator doesn't know the engine control system, then the analyzer is of little or no help. The tester law applies in all circumstances, but right now keep it in mind as we discuss static checks of engine components prior to engine operation.

Bleed valve solenoid check. Insert the free end (black end) of the test lead into the load jack, item 43. Hold the on-off switch, item 52, in the ON position. Current flow should be indicated on the multimeter. If current flow is indicated, release this switch and disconnect the test lead from the jack.

Ignition circuit check. Connect the free end of the test lead to the ignition jack, item 46. Place the on-off switch in the ON position. Current flow should be indicated on the multimeter. If power is indicated, release the switch and disconnect the test lead from the jack.

Fuel solenoid circuit check. Connect the free end of the test lead to the fuel jack, item 45. Hold the on-off switch to the ON position. Current flow should be indicated on the multimeter. If power is indicated, release the switch and remove the test lead from the jack.

HR–1 relay circuit check. Connect the free end of the test lead to the HR–1 rleay jack, item 49. Hold the on-off switch in the ON position. Current flow should be indicated of the multimeter. If power is indicated, release the switch and disconnect the test lead from the jack.

HR–2 relay circuit check. Connect the free end of the test lead to the HR–2 relay jack, item 48. Here, current flow must be indicated on the multimeter and the 35-percent switch light, item 26, HR–1 relay light, item 29, 110–percent switch light, item 28, HR–1 circuit light, item 30, HR–3 circuit light, item 24, and the low oil pressure light, item 5, must all come on. If all of the preceeding are functioning

properly, release the switch and disconnect the test lead from the jack.

HR–3 relay circuit check. Connect the free end of the test lead to the HR–3 relay jack, item 44. Hold the on-off switch in the ON position. Current flow should be indicated on the multimeter. If power is indicated, release the switch and disconnect the test lead from the jack.

Start relay check. To perform the start relay check, disconnect the starter harness, foldout 1, figure 1, item 25, from the battery compartment, item 34. Connect the free end of the test lead to the starter cutout jack, item 47. Then place the on-off switch in the ON position. Current flow should be indicated on the multimeter and the motor rotate light, item 27, must come on. If power is indicated, release the switch and disconnect the test lead from the jack.

When the preceeding checks are completed, place the master switch in the OFF position and reconnect the starter harness to the battery compartment.

Exercises (505):

1. What is the purpose of the preoperational inspection?

2. The positive and negative leads supplied with the test stand for the multimeter are distinguished by what colors?

3. What is the free (black) end of the multimeter lead used for?

4. Match the letter correspondong to the test stand analyzer panel components in column B with the items in column A that are statically checked prior to engine operation. Column B entries may be used more than once.

Column A	*Column B*
____ (1) 35-percent switch illuminates.	a. +24V DC jack.
____ (2) Motor Rotate light illuminates.	b. Load jack.
____ (3) Current flow is indicated only on the multimeter.	c. Ignition jack.
____ (4) 110-percent switch light illuminates.	d. Fuel jack.
____ (5) Low oil pressure warning light illuminates.	e. HR–1 relay jack.
____ (6) The red end of the test lead is inserted into this jack.	f. HR–2 relay jack.
____ (7) HR–1 circuit light will illuminates.	g. HR–3 relay jack.
	h. Starter cutout jack.

506. Specify the starter motor operating cycle and the indication that the fuel system is properly primed, and indicate the length of time to motor the engine for proper oil system priming.

Priming the Engine Fuel and Oil Systems. Whenever the engine fuel and oil systems have been drained, the engine must be motored until a positive indication of pressure in these systems is indicated. Priming assures that the engine gets ample lubrication during operation. A key factor in these priming operations is the starter duty cycle. The starter motor duty cycle is 1 minute on and 4 minutes off. This permits a sufficient cooling period to prevent seizure and overheating of the starter components.

Fuel prime. Insuring that an adequate supply of fuel in the test stand is necessary in performing fuel system priming. The hose at the pressure connection on the test stand is disconnected. A container large enough to collect fuel spillage during fuel priming should be used. The engine must never be rotated unless there is an adequate supply of fuel to the fuel pump and control unit. Fuel pump lubrication is provided by fuel, and the pump will fail quickly if it is operated dry. When the master switch and boost pump switch on the analyzer panel are placed in the ON position, check that the lights come on. Place the motor rotate switch in the ON position to rotate the engine by starter motor action. Allow the engine to rotate until an oil pressure is indicated on the indicator. An indication of oil pressure should be observed within 10 seconds. If no indication of oil pressure is evident within this time limit, stop motoring the engine and correct the malfunction. Continue to motor the engine until the fuel flowing from the hose assembly is free of bubbles. Do not exceed the starter duty cycle. Place the switches in the OFF position and connect the hose.

Oil prime. To prime the oil system, make certain that the test trailer oil tank and the connecting line are full of oil. Otherwise, there will be difficulty in priming the oil pump. If necessary, bleed the oil inlet line to assure oil flow to the pump. Place the master switch and the boost pump switch in the ON position. Next, place the starter motor rotate switch in the ON position to motor the engine. Allow the engine to motor until oil pressure is indicated on the oil pressure indicator. If oil pressure is indicated, continue motoring the engine for a total of 60 seconds. After this motoring period, place the motor rotate switch, master switch, and boost pump switch in their OFF positions. This completes the oil priming of the oil pump.

Exercises (506):

1. What is the starter motor duty cycle?

2. How are you able to tell if the fuel system is properly primed?

3. How long should you motor the engine to prime the oil system?

507. Identify various precautions, reactions, and treatments relative to the air intake and exhaust areas before, during, and after engine operation.

Ground Safety Precautions. The operating characteristics of gas turbine engines present several hazards

to your workers. It has always been a standard practice to avoid the propeller on a piston engine, and the same care is necessary in the case of turboprop engines. In addition, the rear of a jet engine presents a hazard that must be avoided. Hot, high velocity gases from the exhaust produce hazardous temperatures at the rear of the engine.

The air intake of the gas turbine draws an extremely large volume of air, thus creating a very high velocity stream near the inlet. This stream of air can pick up any loose material and may even draw a large man's body into the inlet of the engine. Men have been killed or severely injured by being drawn into the intake of an operating engine. After insuring that all of your workers are in safe positions, see that all loose materials are removed from the engine inlet area so that nothing will be drawn into the engine to cause damage. Just before you start the engine, inspect the engine inlet duct to make sure that it is clear of all foreign matter. This inspection must be very thorough because it is easy to overlook such items as cotter pins, safety wire, washers, small nuts, screws, and other small items, any of which can severely damage an engine.

When the gas turbine engine operates at maximum power, the exhaust may pick up and blow loose nuts, bolts, safety wire, and other debris for a considerable distance. For this reason, carefully inspect the exhaust duct. Also, when you park this test trailer, make sure there is nothing above the exhaust duct, such as electrical wires, telephone wires, or other items that could be damaged. The temperatures found at the rear of the gas turbine operating at full power may be high enough to melt or ignite overhead items.

Sometimes excess fuel accumulates in the tailpipe of the engine, and when the engine starts, a long flame will blow out the tailpipe. Be sure that all flammable materials are removed from the area in the rear of the engine.

Tests have indicated that the carbon monoxide content of exhaust gases is relatively low, but other gases are present which have a disagreeable odor and cause eye and nose irritation. The respiratory tract may also be adversely affected if these gases are inhaled in too strong a concentration. In all cases, the breathing of exhaust gases should be avoided.

Gas turbine engines produce noise which is capable of producing temporary and even permanent loss of hearing. Exposures to extreme noise may result in damage to the eardrum, and all persons working around operating engines should wear some form of ear protection.

After engine operation, do not work on the hot section of the engine. Allow adequate time for hot-section cooling. If you must work in the hot section, wear asbestos gloves.

Gas turbine engines are normally equipped with high-intensity ignition systems capable of causing severe injury or death. Do not work on the ignition system or igniter plug while the engine is operating. Take all the care necessary to avoid the possibility of shock from the system.

Fuels and lubricating oils should not be spilled on the skin. Fuels have strong drying effect on the skin and may cause considerable irritation. Lubricating oils, especially the synthetic type, may have an irritating effect. If clothing should become saturated with either fuel or oil, remove it at once and wash the skin with soap and water. Always remember that you are a walking fire hazard if your clothes are saturated with fuel or oil.

Exercises (507):

1. Prior to engine operation, what precautions should be taken at the air intake?

2. What are some symptoms of exhaust gas inhalation?

3. If it becomes necessary to work in the engine hot section immediately after engine shutdown, what should the worker wear to avoid skin burns?

4. How should fuel and oil be removed from the skin?

508. State the benefit of engine warmup and name two types of warmup before loading the engine, specify the lights and the switch that activate during the test, and identify the normal condition for the cooling air fan.

Engine Operation. Whenever practicable, plan the operation of the engine in advance to allow time for a 1 to 5 minute warmup period at governed speed prior to loading. This is not mandatory, but is recommended whenever possible. Observing a preliminary warmup procedure reduces the rate of temperature change and lessens thermal stress across the turbine wheel, thereby prolonging the life of the unit.

Types of runs. Replacement of externally mounted accessories requires only a functional check of the associated system. This check may be performed in the engine cart. However, if integral parts of the gas turbine engine have been repaired or replaced, you must take a complete performance check of the engine.

Starting the gas turbine engine. Operate the engine during performance testing under both manual and automatic control. Refer to foldout 1, figure 2, for this portion of the text.

Push in the circuit breaker, item 17. Place switches, items 32–38 and items 40–42, on the test stand analyzer panel in the ON position. See that the load switch, item 31, and the motor rotate switch, item 39, are in the OFF position. Place the master switch, item 14, and the boost pump switch, item 15, in the ON position and see that lights, items 10 and 11, come on. At this time, actuate the start switch, item 16, and verify that the following lights come on, items 5 and 23–30. Control the speed of the engine manually, when required, by manipulating the manual speed control valve, item 12. Monitor the oil pressure indicator, item 8, the exhaust gas temperature indicator, item 2, and the fuel pressure indicator, item 7, during engine starting and throughout

engine operation. The engine must be shut down immediately and the cause of the trouble determined and corrected if the operation limits exceed TO limits. Also, if seizing, unusual noises, smoke, fuel or oil leakage, or other obvious malfunctions are observed, shut down the engine. Check to see that the low oil pressure light, item 5, goes out, and the fuel light, item 21, and the ignition light, item 22, come on indicating rising oil pressure.

When the engine reaches 14,900 to 16,900 rpm, check to see if the 35-percent switch actuates. The following lights go out: items 23, 25, 26, and 27.

When the engine reaches 37,000 to 39,000 rpm, check that the 95-percent switch actuates. The ignition light, item 22, should go out and the HR–3 relay light, item 20, and load lights, items 19 and 4, come on.

When the engine reaches no-load governed speed, see that the tachometer indicator indicates 41,900 to 42,100 rpm. A table in the intermediate maintenance TO will convert these direct readings to a more convenient form. Also, check the oil pressure indicator to see if the oil pressure is within prescribed TO limits. Actuate the load switch and monitor the exhaust gas temperature. Check the cooling air fan to see if it is pulling in air. If the fan is blowing out air, shut down the engine and check for proper cooling fan assembly.

When the tests and adjustments are satisfactorily completed, place the stop switch in the OFF position and shut down the unit. Engine adjustments will be covered later in this chapter.

Exercises (508):

1. What benefit does a preliminary warmup period have prior to loading the engine?

2. What are two types of runs performed on the gas turbine engine?

3. When the start switch is actuated, which lights on the analyzer panel come on?

4. What switch is actuated when the engine reaches 38,000 + 1000 rpm?

5. When the cooling air fan is correctly assembled, it is __________ __________ air.

509. List four characteristics required to complete AFTO Form 99 and the entties recorded on the top of the form, name the component responsible for a given condition, compare partial test log entires against the tables, and complete the test log.

Test Log. For each engine tested, an AFTO Form 99, Small Gas Turbine Test Log, is completed. This log is used for recording observed data during engine testing. Since the log provides a permanent record of the engine test, this record provides future references and acts on documented proof that the engine was subjected to the prescribed test procedures. The data recorded on this test log must be complete, accurate, neat, and legible.

Test log entries. All of the blocks on the AFTO Form 99, foldout 2, are not filled out. The major performance requirements that the engine is subjected to after repair are shown in tables 6–1A and 6–1B. Remember, these tables and the limits shown are for CDC use only, and you must use current technical orders for engine testing. Additional test log entries are totally dependent on the extent of maintenance performed on the engine. The partially completed test log shown in foldout 2 was prepared for an engine being tested for a turbine component replacement. The entries that are recorded on this form represent an actual engine operation. They are representative figures only for CDC use. Local directives and policies may require you to test the engine beyond technical order requirements.

The following entries are recorded on the top of the form:

- The date the engine was tested.
- Engine serial number.
- Temperature, wet and dry. Wet and dry temperatures are obtained using a psychrometer.
- Barometric pressure.
- Engine start and stop time.

Starting with the left side of the form, notice that there are two columns. The extreme left column is used to record readings prior to making engine adjustments. The following column is used to record readings after engine adjustments have been made. The Maximum EGT and Unload EGT blocks are also divided into two parts. An indicator and leads have to be connected to the engine thermocouples to obtain these readings. Place these readings in the blocks indicated by unit. The test reading is obtained and transcribed to the form from the exhaust gas temperature indicator, foldout 1, figure 2, item 2, on the analyzer panel. Also, Maximum Fuel Pressure, Fuel Control Air Pressure, Oil Pressure Set, Oil Temperature, and Accessory Case Pressure readings are taken from the analyzer panel, items 7, 6, 8, 9, and 2 respectively. Of special interest is the accessory case pressure. Because of the action of the scavenge oil pump, the accessory case pressure is normally less than the compressor inlet pressure; this aids the seal in keeping the oil in the accessory case and out of the compressor airflow. Large air leaks in the case or poor scavenge pump efficiency can cause loss of accessory case pressure, and allow oil to enter the compressor inlet, increasing oil consumption and contaminating the compressor air.

The extreme right portion of the AFTO Form 97 is used to record performance and test requirements. During a typical gas turbine performance test, check the engine air shutoff valve and estimate bleed airflow by using the test kit and a bleed airflow and total pressure calculator assembly. To decide whether an engine has acceptable performance, you must know the minimum acceptable performance for the engine, as defined in the intermediate maintenance TO. You must then measure the actual performance of the engine being tested. The two important parameters of performance that must be measured are bleed air pressure and bleed

airflow. You must see that at least the amount of flow shown in the TO can be bled from the engine without producing any engine distress, such as surge or overtemperature. In addition, the engine must be able to maintain at least the minimum pressure given in the TO while flowing this air. Essentially, the test kit and calculator calculate flow by measuring the air density, its pressure drop through the valve, and the effective area of the valve through which the flow passes.

Midway through the form on the extreme right is an accepted and rejected block. The operator checks one of the blocks and signs his or her name. Also, the recorder of the form signs the recorder block. In the remarks section of the form, all unusual occurrences and remarks are recorded in this section. If you reject the engine, explain why in the remarks section. This will aid shop workers to expediently repair the engine and return it to an operable status.

Comparing test log entries with TO specifications. Testing the engine consists of operating it in the test stand and recording operating data on the test log. This data is then compared with TO specifications to insure that the engine is operating within the acceptable operating ranges. This comparison of the test data with TO specifications reveals the operating condition of the engine and any need for adjustment or replacement of units. Notice on foldout 2, on the first run, that the oil pressure and fuel cracking pressure were adjusted improperly. The adjustments were made and recorded on the test log. Tables 6-1A and 6-1B show the item requirements.

Exercises (509):

1. List four requirements for completion of the AFTO Form 99.

2. List the entries that are recorded on the top of the AFTO Form 99.

3. During engine operation, smoke is noticed coming from the engine exhaust section and a negative pressure is indicated by a -1 inch Hg on the analyzer panel indicator. Which component could cause this condition?

4. What two factors must be known by the operator in order to decide whether the engine meets performance and test requirements?

5. Using tables 6-1A and 6-1B, compare recorded test log entries against TO specification and check the Accepted or Rejected block on the AFTO Form 99, foldout 2, and sign the AFTO Form 99. If you decide to reject the engine, give a brief description of the reason in the Remarks section of the form.

6-4. Adjustment of Engine Systems Components

Your job may require you to start, operate, and shut down small gas turbine engines in their respective test cells. While you operate an engine, you should observe instruments and indicators, and relate their readings to the operating condition of the engine. When you find abnormal conditions, you must then analyze them to locate the possible cause of the trouble. If you decide that there are several possible causes, it is a good practice to eliminate the most easily corrected troubles first. This may entail a simple adjustment.

In this section, we explain the adjustments which are made on the plumbing system. There are three subsystems under the plumbing system; fuel, lubrication and pneumatic. No explanation of the electrical system adjustments will be mentioned in this section as it was previously discussed in Volume 1.

510. Specify the two functions of the engine fuel system and associate fuel system components to their functions or adjustment procedures.

Fuel System. The fuel system is fully automatic in operation and does not require the manipulation of its control by the operator. After actuation of the test stand start switch, the fuel system functions to provide the correct amount of fuel flow for smooth acceleration of the engine to 100-percent speed; thereafter, it modulates the fuel flow as necessary to keep the gas turbine's speed constant under varying air bleed and electrical loads. Provisions are also incorporated to protect the turbine from excessive temperature during its acceleration and from overload conditions.

The first requirement of the fuel system is speed control. The gas turbine derives its power from the burning of fuel, the flow which must be regulated to control the power developed, and, thereby, to control the speed.

Another requirement of the fuel system is to provide fuel flow during acceleration in such a manner that the maximum turbine temperature is not exceeded and yet the engine will accelerate in the shortest possible time. In controlling the fuel flow during the acceleration of the turbine, two basic assumptions are relied on:

(1) Measuring the fuel pressure provides a measurement of fuel flow through the fuel atomizer.

(2) Compressor pressure is a reliable indication of turbine airflow.

If these two assumptions are correct, then it follows that if the compressor pressure is used to control fuel pressure, then the fuel flow will be proportional to the turbine airflow. The first requirement is fulfilled by the speed governor. The acceleration limiter functions to satisfy the second requirement.

Acceleration limiter valve adjustment. Referring to figure 6-3 the acceleration limiter valve operates on the principles

TABLE 6-1A
ENGINE TEST REQUIREMENTS AND OPERATING LIMITS

Item	Requirements	Remarks
a. FUEL	MIL-T-5624, Grade JP-4 or JP-5	Filtered and supplied at 43°C (110°F) (MAX) and 5 ±2 PSIA.
b. LUBRICANT		
Specification	MIL-L-7808D, F or G	
Oil pressure (turbine)	90 ±10 PSIG	Except below 30,000 RPM
Oil pressure accessory assembly	45 ±10 PSIG	Except below 30,000 RPM
Oil pressure fluctuation	±3 PSI (MAX)	Under steady state operating conditions. Measured at the pressure sensing connection.
Oil temperature	Shall not exceed 65°C (150°F) above inlet air total temperature.	
c. ELECTRICAL SUPPLY	24 VDC	
d. TEMPERATURES		
Compressor	251°C (483°F) (MAX)	Except during overspeed switch check. During overspeed switch check, do not exceed 251°C (483°F) for longer than 10 seconds.
Turbine discharge	677°C (1250°F) absolute (MAX)	Never exceed at any time under any conditions.
Turbine discharge	663°C (1225°F) (MAX)	At any maximum load condition. Run for two-minute cooling period before a test cycle is repeated, if the unit has been operated at a temperature higher than 663°C (1225°F).
Inlet air	54°C (130°F) (MAX)	
Fuel	57°C (135°F) (MAX)	Measured at the fuel pump inlet.
Oil	Shall not exceed 66°C (150°F) above inlet air total temperature.	
e. STARTER MOTOR DUTY CYCLE	1 MIN on, 4 MIN off	Maximum
f. LIGHT-OFF TIME	5 SEC (MAX)	Starting after 5 PSIG oil pressure is attained.

TABLE 6-1B
ENGINE TEST REQUIREMENTS AND OPERATING LIMITS

Item	Requirements	Remarks
g. TURBINE WHEEL SPEEDS		
Continuous operation	42,000 ± 100 RPM	No load or loaded condition.
Absolute maximum	44,500 RPM	For overspeed checks only.
10-second operation	44,100 to 44,500 RPM	Do not operate for longer than 10 seconds.
h. VIBRATION		
Accessory assembly	0.6 mil (MAX)	Peak vibration generally occurs at a turbine wheel speed of 30,000 ±2000 RPM.
Turbine	0.4 mil (MAX)	Peak vibration generally occurs at a turbine wheel speed of 30,000 ±2000 RPM.
i. BLEED-AIR OSCILLATION	±1.0 IN. Hg (MAX)	Steady-state operation within the operating limits of the unit.
j. ACCESSORY CASE AND TURBINE PRESSURES		
Accessory case pressure	At least 2 IN. Hg gage (negative)	During governed speed operation.
Turbine cavity vent pressure	+2 PSIG (MAX)	During governed speed operation.
k. LEAKAGE		
Air		Permitted only from: (1) Load control valve bleed holes. (2) Air pressure regulator. (3) Acceleration limiter valve cap on fuel control assembly. (4) Plenum drain valve during reduced speed operation.
Fuel	One drop per minute (MAX)	From accessory drain only. Fuel leakage from the plenum drain is permitted after a false start or blowout.
Oil (from shaft seals)	One drop per fifteen minute period.	
Oil (from drive seal)	3 drops (MAX)	From first-stage compressor drive seal during and/or immediately following each deceleration.

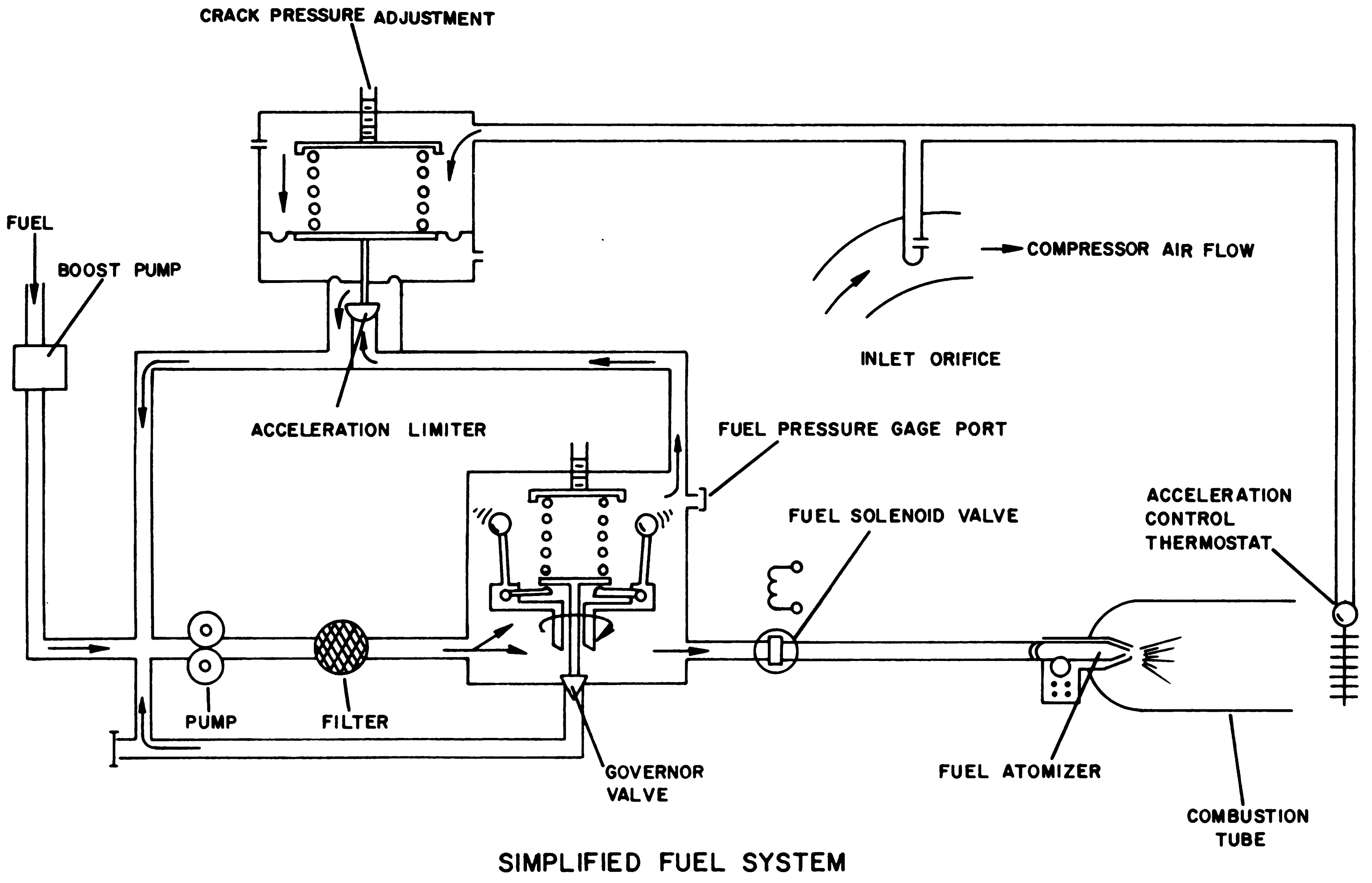


Figure 6–3. GTCP85–180 fuel system.

of air pressure and spring pressure versus fuel pressure. Its purpose is to control the fuel pressure of the turbine during starting and acceleration up to 95-percent turbine speed. Air pressure from the plenum is used as the controlling air. Air pressure increases as turbine speed increases. This control air, together with spring pressure, is applied to the diaphragm in the acceleration limiter valve. It regulates the amount of fuel that is allowed to bypass back to the fuel pump inlet. As the control air pressure rises, less fuel is allowed to bypass to the fuel pump inlet, and the fuel pressure to the atomizer is increased.

When the compressor first begins to turn, there isn't enough control air pressure to allow enough fuel to reach the atomizer for lightoff. This is overcome by the spring that acts on the diaphragm. The spring pressure is adjustable. This adjustment is called acceleration limiter pressure (crack pressure). The value of this crack pressure is adjusted by motoring the unit with the control air line disconnected, and the fuel pressure line, foldout 1, figure 1, item 42, disconnected and connecting a pressure gage on the fuel pump and control unit. The spring is adjusted to obtain the value prescribed by the technical order. To increase fuel pressure, turn the adjustment screw clockwise and to decrease pressure, turn the screw counterclockwise.

Governor trim control adjustment. At 95-percent turbine speed, plenum pressure has increased to the point where it overcomes fuel pressure in the acceleration limiter valve. This causes the ball to close on its seat and block fuel from the main fuel pump (see fig. 6-3). The governor then assumes control of the fuel pressure to the atomizer and maintains governed speed (100 percent).

When the unit reaches 95-percent speed, the centrifugal force generated by the spinning flyweights, is great enough to move the sleeve, which is being held in place by spring pressure. The spring pressure is just enough to allow a certain amount of fuel to return to the inlet side of the main fuel pump. This action controls the fuel pressure at the atomizer, keeping the unit at 100-percent speed.

To make the governor trim control adjustment, figure 6-3, disconnect the electrical connection at the governor trim control assembly and remove the cover. Start and accelerate the engine under manual control to a no-load speed of 42,000 rpm. Loosen the clamp screw on the quadrant and rotate the governor drive shaft counterclockwise to obtain a high-speed stop setting of 42,800 +100 rpm. Rotate the quadrant clockwise and adjust the low-speep stop to obtain a minimum governor setting of 40,000 +100 rpm. Reinstall the cover and electrical connection to the governor trim control assembly. Activate the motor and vary the speed of the engine throughout the range to check the stop settings.

Pneumatic control thermostat adjustment. The pneumatic control thermostat, figure 6-4, is a normally closed thermostat which operates in two different modes: acceleration and pneumatic mode. It works together with the normally open thermostat selector solenoid valve. When this valve is open, the thermostat is in the acceleration mode. Once the engine reaches 95 percent and the bleed air switch is turned on, then this solenoid closes and the thermostat is operating in the pneumatic mode.

In the event bleed air and shaft power demands exceed the capacity of the engine, the thermostat will limit the amount of bleed air provided. The thermostat has a maximum setting of 646° to 649° C. (1195° to 1200° F.). The thermostat must be set with the acceleration mode setting within 50° C. (100° F.) of the pneumatic mode setting.

When an overtemperature occurs during acceleration, the thermostat functions to reduce air pressure to the acceleration limited valve. The acceleration limiter valve then starts bypassing fuel. The result is that less fuel pressure is applied to the atomizer and the overtemperature condition is reduced.

The pneumatic control thermostat is essentially a spring loaded ball attached to a kentanium rod, which is welded to a steel housing, see figure 6-4. The upper end of the housing contains a threaded boss which receives the control air line from the acceleration limiter valve. Dissimilar materials are used for the rod and housing. Each expands at a different rate when heated. When the turbine discharge temperature is low, the housing contracts more than the rod and the ball closes off the line fitting. No control air is lost under this condition. As the temperature of the turbine increases, the housing expands, pulling the rod and the ball away from the end of the line fitting, allowing control air to escape. The thermostat is adjusted by varying the number and size of shims between the line fitting and the housing. Decreasing the thickness of shims increases the setting of the thermostat. A change of .001 inch is the total shim thickness will equal approximately a 17° C. change in the temperature setting of the thermostat.

The pneumatic mode of operation will be discussed in behaviorial objective 512.

Exercises (510):

1. What are the two requirements of the fuel system?

2. Match the letter corresponding to the fuel system component in column B with the function or adjustment procedure in column A. Column B entries may be used more than once.

Column A	*Column B*
____ (1) Limits engine rpm at 100 percent.	a. Acceleration limiter valve.
____ (2) Air line must be disconnected prior to making adjustment.	b. Governor.
____ (3) Adjustment is accomplished with the use of shims.	c. Pneumatic control thermostat.
____ (4) Controls fuel pressure up to 95 percent.	
____ (5) Operates on the principle of air pressure and spring tension versus fuel pressure.	
____ (6) If turbine temperature tries to exceed the allowable limit, this component automatically bleeds air from the control airline.	
____ (7) Governs engine speed above 95 percent.	
____ (8) When the pneumatic control thermostat opens this component bypasses fuel back to the inlet side of the fuel pump.	

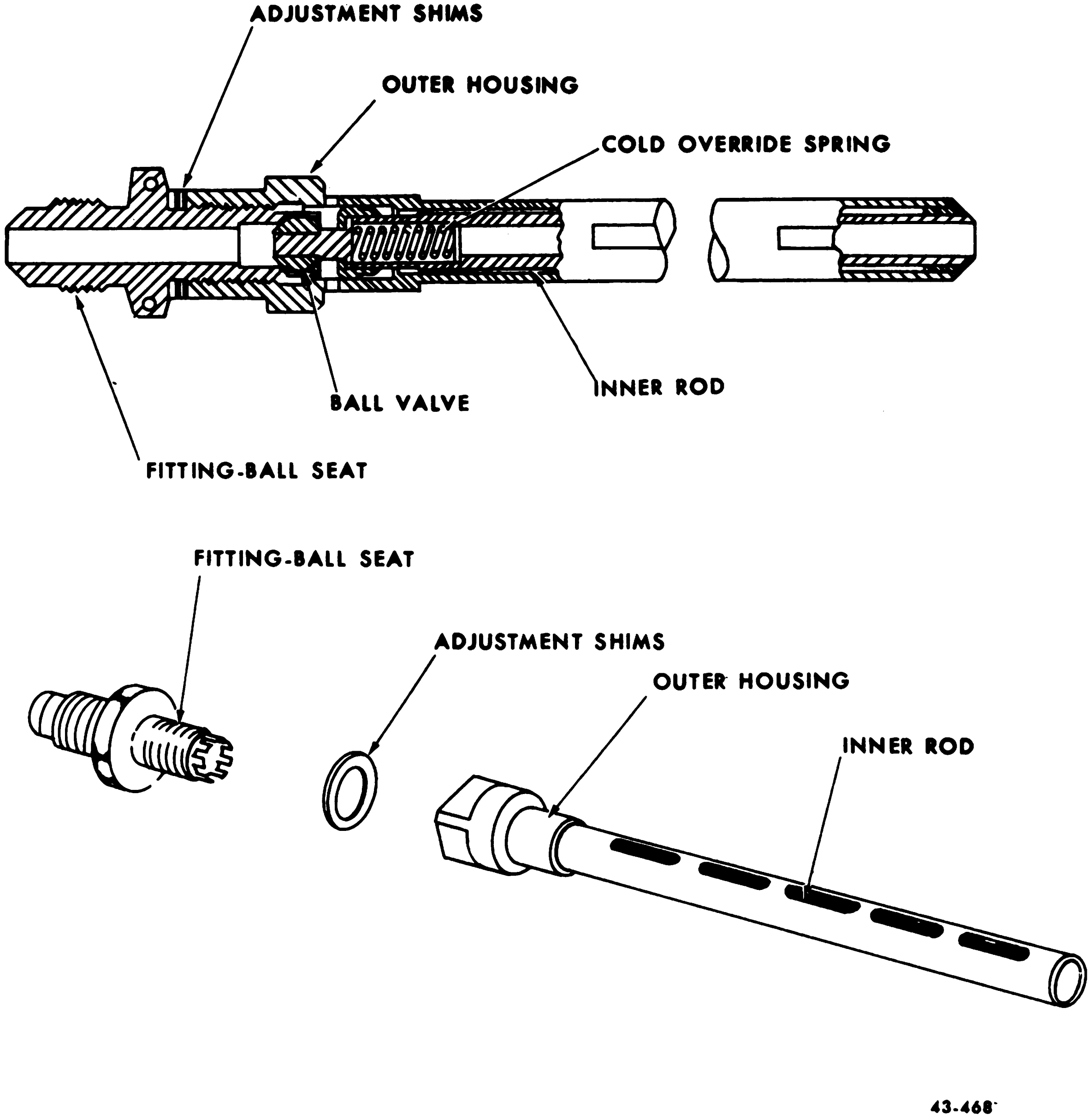


Figure 6–4. Pneumatic control thermostat.

511. Specify how to install the oil pressure relief valve, how it works, and how to adjust oil pressure with it.

Lubrication System and Adjustment. The lubrication pump is designed to produce a greater volume flow than is normally required by the oil system. When the pump attempts to force this excess oil flow through the jets and passages, a high-pressure results. The excess pressure and, thus, excess flow is relieved back to the pump inlet through a spring loaded oil pressure relief valve assembly. This relief valve is located on the oil pump assembly. Its construction is shown in figure 6-5. This valve is set to regulate pressure to provide proper lubrication for the gears and bearings through the restrictive passages and oil jets in the oil system. During engine operation, monitor the engine oil pressure on the indicator, see foldout 1, figure 2, item 8. If the oil pressure is not within the operable range, adjust the screw on the oil pressure relief valve assembly. Turn the screw clockwise to increase pressure and counterclockwise to decrease pressure.

Exercises (511):

1. On what major assembly is the oil pressure relief valve mounted?

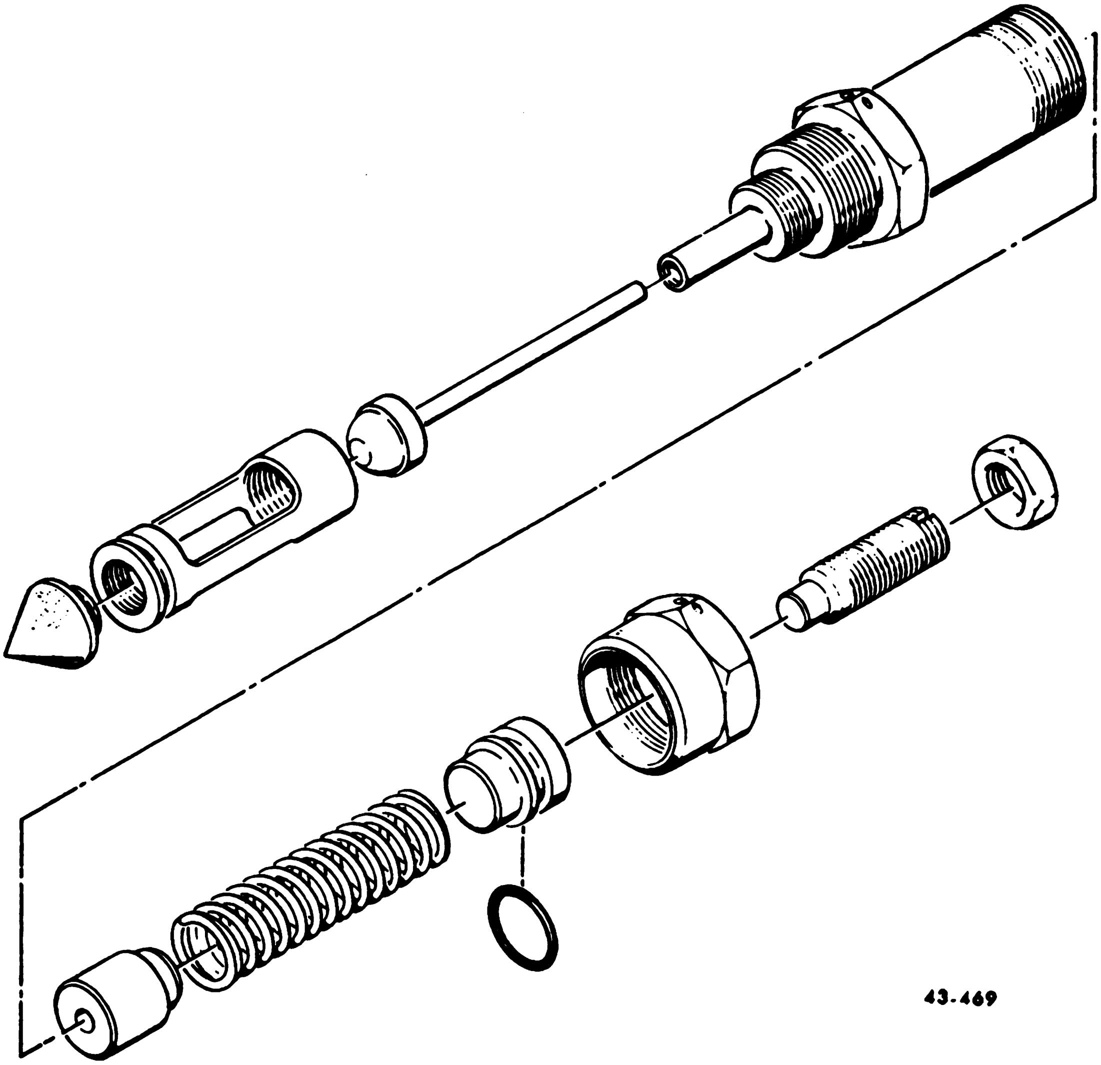


Figure 6–5. Oil pressure relief valve assembly.

2. What component of the oil systems controls oil pressure?

3. Excess oil that is bypassed during engine operation is returned to the inlet side of the ____________________.

4. To increase oil pressure, turn the adjustment screw in the __________ direction.

512. State the purpose of the bleed air system and specified components and how adjustments are made on specified components.

Bleed Air System and Components. The bleed air system consists of only three primary components: differential pressure regulator, unloading air shutoff valve, and load control thermostat. These three components control the supply of high-volume, low-pressure air for starting jet engines that use pneumatic starters.

Differential pressure regulator. The purpose of the differential pressure regulator is to maintain a constant air pressure to the load control valve. The normal output of the regulator is 18–20 psi. This output air pressure controls the operation of the load control valve. The air from the second stage is generally 30 psi or higher. When the regulator is properly adjusted it reduces the second stage air to the required value.

The controlled air pressure is then sent to the load control switcher valve in the load control valve. The switcher valve is operated by the switcher valve solenoid which, in turn, is actuated by the bleed air switch on the control panel.

Load control valve assembly. The heart of the bleed air system is the load control valve. This valve consists of four air chambers, an actuating rod and diaphragm, and a 4-inch diameter butterfly valve. Chambers 1 and 2 are used to open and close the butterfly valve. A spring in chamber 1 aids in closing the valve. Chambers 3 and 4 control the valve operation.

When the bleed air switch (load switch) is placed in the LOAD position, air is directed by the switcher valve to chamber 2. The air pressure causes the actuating rod to move down which opens the butterfly valve. Once the valve is open, compressor discharge air is allowed to flow from the turbine plenum chamber. This discharged air can then be used to operate any pneumatic component such as engine starters and aircraft air-conditioning systems.

Chambers 3 and 4 are called the rate control valve. The purpose of this valve is to control the rate of opening of the butterfly valve. When properly adjusted, this rate will be between 6 and 10 seconds. If the engine speed reduces excessively when a pneumatic load is applied to the engine, the rate control valve is improperly adjusted. Turning the slotted screwhead clockwise will cause the rate control valve to open slower, thus preventing momentary overloads and their undesirable effects. If the butterfly is allowed to open too quickly, even during adjustment, internal damage to the engine may result.

Pneumatic mode of the pneumatic thermostat. When the engine is loaded, exhaust gas temperature will increase because of both the reduction in cooling air and the increased fuel flow to the engine. When the temperature of the exhaust gases approaches the setting of the pneumatic thermostat, the valve will open. This action allows some of the pressure in chamber 2 to be bled off. The partial loss of pressure causes the actuator diaphragm return spring to partially close the butterfly valve. This action reduces the amount of air flowing from the control valve and provides more air for engine cooling. As the exhaust gas temperature decreases, the butterfly valve will again open as pressure increases in the chamber. The system will stabilize to provide output air at the maximum temperature range. The setting of the load control thermostat is adjusted by means of shims in the thermostat body. However, you should remember to use the TO when performing any adjustments. The setting of the exhaust gas temperature is critical to the operation of the turbine engine.

Exercises (512):

1. What is the purpose of the bleed air system?

2. Control air for operation of the load control valve is provided by what?

3. The opening time of the load control vale is controlled by what?

4. How is the rate control valve adjusted?

5. What is the function of the pneumatic mode of the pneumatic thermostat?

6. How is the pneumatic thermostat adjusted?

Noise Suppressors and Special Equipment

DURING THE TIME you have been in the Air Force, you have seen and used a lot of special equipment. This equipment helps you to do your job better, easier, or safer. In the case of noise suppressors, you also improve community relations besides providing a safer environment and protecting your hearing.

In this chapter, we discuss both aircraft and test cell noise suppressors. We also discuss some of the special test equipment you will use to do your job.

7-1. Noise Suppressors

The Air Force now uses noise suppressors. You will find noise suppressors being used for test cells, and wherever possible, they will also be used for the aircraft.

Why are noise suppressors being used so much? Noise pollution is prevalent around any flight line, and whatever can be done to reduce noise will be very beneficial to our environment. Noise is also a hazard to the health of the mechanics working on or near aircraft with operating engines. The use of noise suppressors protects these people, as well as everyone nearby, who would otherwise be bothered by the noise.

The operation and maintenance of the noise suppressors will be part of your job. When the suppressors are used properly they do not interfere with the engine operation and they reduce the noise to a level which is acceptable. Noise suppressors also help our relations with the surrounding community by eliminating much of the irritation which is normally generated by the noise of jet engine operation.

513. State the purpose of a noise suppressor when operating aircraft engines, identify the steps required to position an aircraft in the noise suppressor, and state the requirement for an adequate water supply.

Aircraft Noise Suppressors. Most of the fighter and trainer aircraft in use today have noise suppressors designed to be used with them. When you have to run an installed engine, the aircraft should be placed in the noise suppressor if one is available. This procedure is a rather involved process, but it is one that will maintain good community relations, as well as help protect the environment and your mechanic's hearing.

An aircraft noise suppressor is shown in figure 7-1. You will notice that the aircraft is aligned in the suppressor by main wheel guides, item G, and a nose wheel guide, item J. The aircraft is locked in position with the wheel chocks which are provided. Check the primary air silencers, item H, for foreign objects, debris, and loose parts. Now position these air silencers so the rubber bumpers just touch the aircraft and lock the silencers to their tracks. Connect the air pressure hose to the silencers and pressurize the seals. Do not exceed 3 psig at any time.

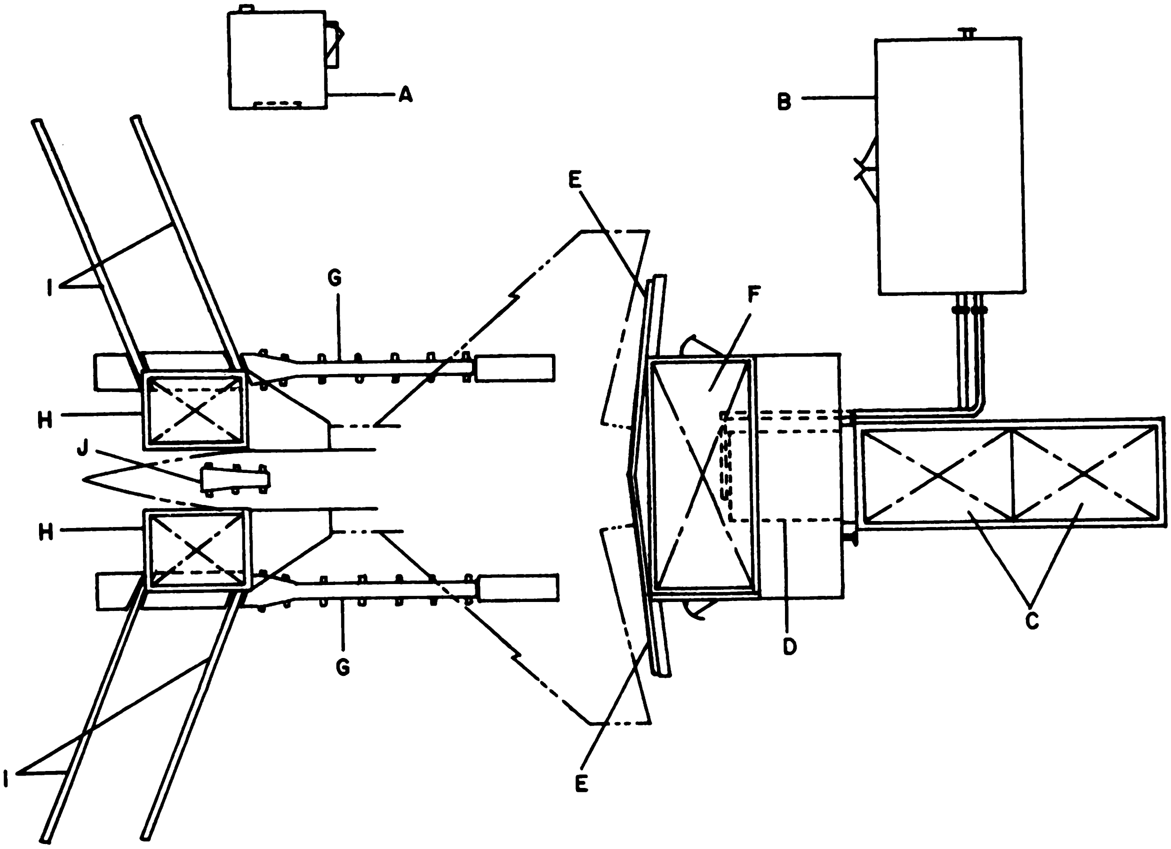
Close the retractable doors, item E, on the exhaust silencer enclosure. The doors should close around the aircraft and the seal should just make contact with the aircraft skin. Once the doors are properly positioned, pressurize the seal. Do not exceed 3 psig at any time.

The reason the seals on both the primary and exhaust silencers are pressurized is to assure a good tight fit. This prevents noise from escaping around the silencers. Around the primary air silencers the seal also assures that FOD cannot be sucked into the engine through gaps in the seal.

Before using the noise suppressor, you must first check out the systems to make sure everything is in good condition and will operate as it should. Check the control house, item A, for power and that the ventilation system is working. In the pump house, item B, make sure the water valves are on and that the pumps are working. Also, check to see that there is an adequate water supply to cool the exhaust silencer. The exhaust silencer will use up to 800 gallons of water per minute during afterburner operation.

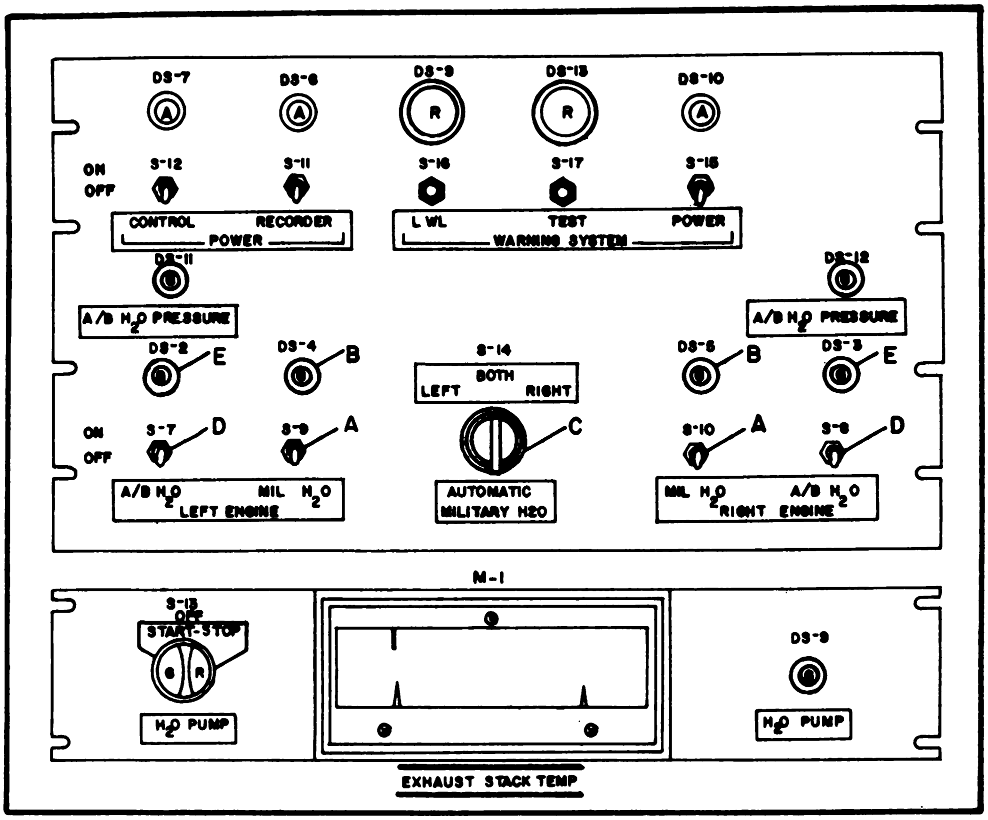
Check that the seals on both the primary and aft silencers make full contact with the aircraft. Connect the interphone system and prepare to run the engines. With the aircraft installed in the noise suppressor, you may operate the aircraft with a substantial noise reduction. The suppressor, though, will not affect the operation of the engine in any way. The suppressor is not designed to allow both engines to be in afterburner at the same time, though you may run both at military power at the same time. When running in afterburner, you must reduce the other engine to idle.

While the engines are operating there must be an operator in the noise suppressor control house at all times. The person in the control house is responsible for operating the water control panel, figure 7-2. This person must be in constant contact with the aircraft operator at all times. This contact is maintained through the use of an interphone system. Any time an engine is to be advanced above idle, the person in the control house must be notified. The noise suppressor operator will turn on the military water switch, item A, for the engine being operated. This will produce a water flow of approximately 75 gallons per minute into the noise suppressor diffuser. The amount of water flow will be indicated on the two pen recorder, similar to the one shown in



A. Control house
B. Pump house
C. Exhaust silencer
D. Diffuser
E. Retractable doors
F. Exhaust silencer enclosure
G. Main wheel guide
H. Primary air silencers
I. Primary air silencer tracks
J. Nosewheel guide

Figure 7–1. Aircraft noise suppressor.



A. Military water switch
B. Military water flow light
C. Automatic military switch
D. A/B water switch
E. A/B water flow light

Figure 7–2. Water control panel.

figure 7-7, located in the control house. Green lights, item B, will also illuminate to indicate that there is water flow. If both engines are to be operated at military power, the automatic military switch, item C, must be placed in the BOTH position. This switch will always correspond to the engine being operated above idle. When the engine is to be operated in the afterburner range, the A/B water switch, item D, for that engine will be on and the green indicator light, item E, will be illuminated. During afterburner operation a water flow of 725 + 50 − 10 gallons per minute must be indicated on the two pen recorder. If there is not enough water sprayed into the noise suppressor diffuser to cool it, severe damage can be done by the heat of the engine exhaust.

After the engine run is completed and the water systems shut down, remove the aircraft from the noise suppressor. The suppressor must now be inspected for damage incurred during the engine run. Any damage must be repaired before another aircraft is operated.

Exercises (513):

1. Give the reasons for using a noise suppressor in an aircraft.

2. List the steps necessary to install an aircraft in the noise suppressor.

3. Why is it so important to insure there is an adequate supply of water?

4. What is the operator in the noise suppressor control house responsible for?

5. How is water flow indicated?

514. State how engine noise suppressors work, how they are cooled, and what maintenance inspection they require.

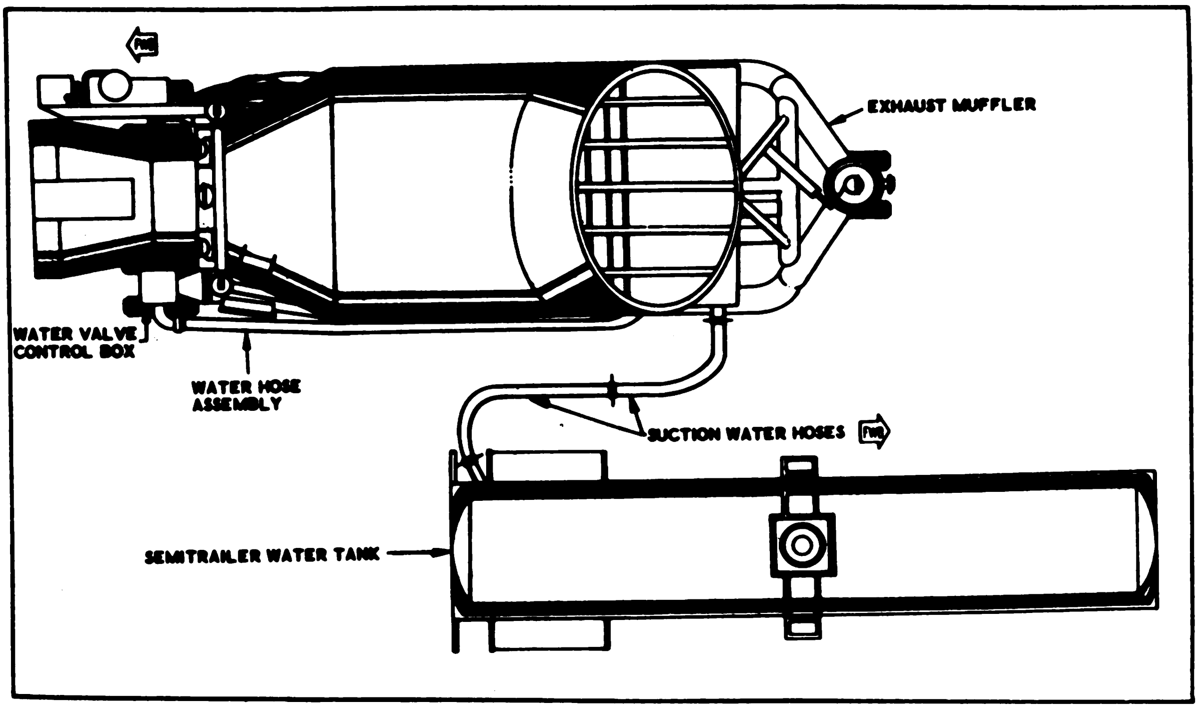
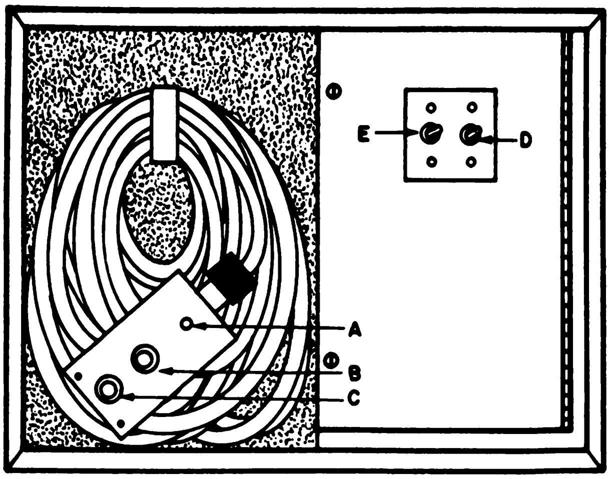


Figure 7–3. Portable engine noise suppressor.



A. Water control switch
B. Water ON light
C. Water OFF light
D. No. 2 heater circuit breaker
E. No. 1 heater circuit breaker

Figure 7–4. Water control box.

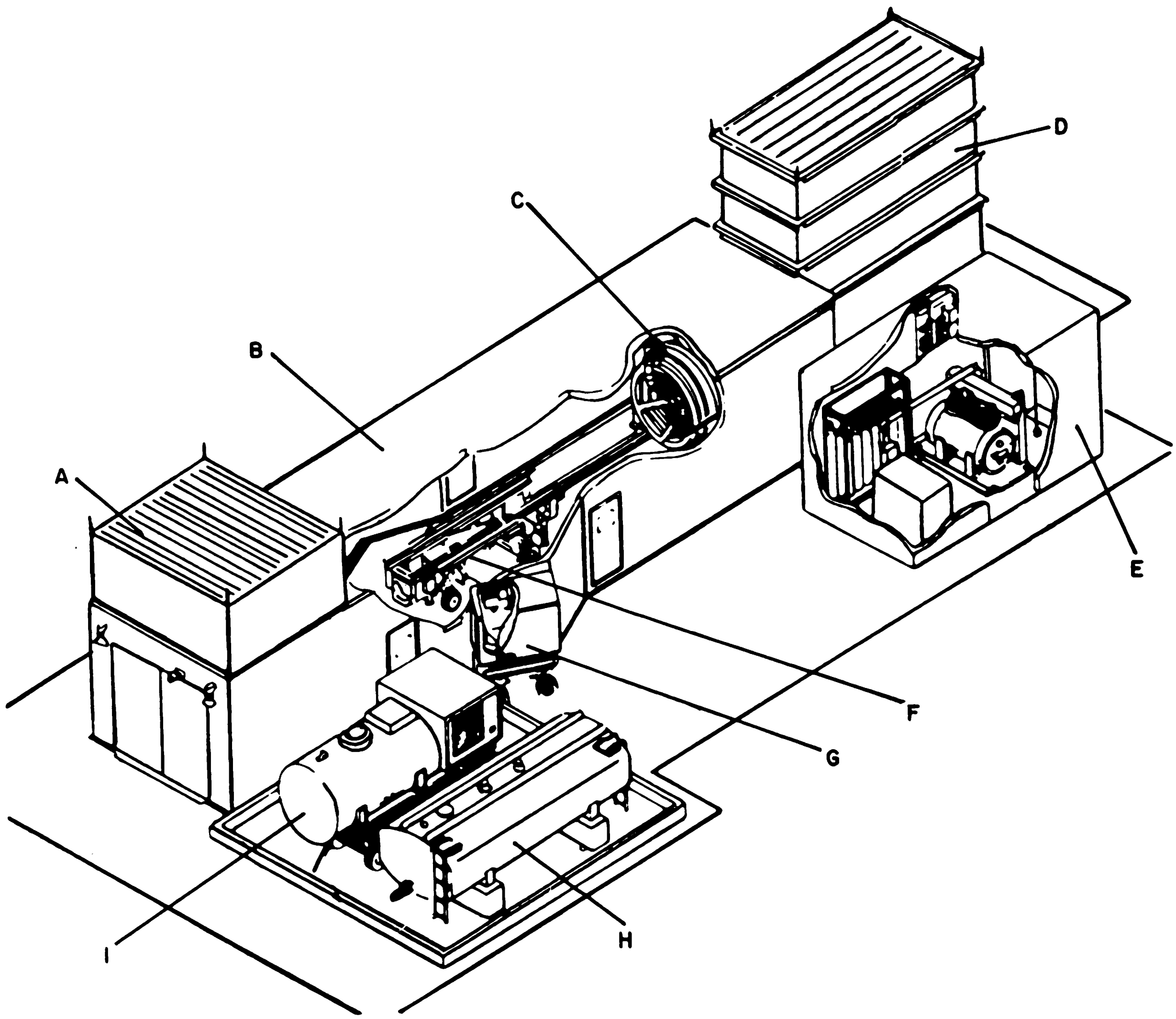
Engine Noise Suppressors. The Air Force uses several types of engine noise suppressors. These suppressors are both portable, figure 7-3, and fixed. Almost all engine noise suppressors are similar in nature and do their job effectively.

Portable noise suppressors. The portable noise suppressor shown in figure 7-3 has an exhaust muffler which absorbs the exhaust noise through the use of acoustical panels and then directs the exhaust gases upwards. A water sparger (spray nozzle) is used to cool the muffler during afterburner operation. Water cooling is not required during nonafterburner operation. The 4000-gallon water tank, figure 7-3, is not needed if a fire hydrant is available and authorized for use. The water tank has a gasoline engine which is used to drive a water pump to supply water under pressure to the water sparger. The intake muffler is positioned in front of the engine and absorbs the intake air noise. This is done through the use of acoustical panels inside the muffler.

With the noise suppressor positioned and the water connected, start the gasoline engine and pressurize the water system to insure water flow. Place the cooling water control box, figure 7-4, with the engine operator in the test cell control house. Whenever the engine is to be run in the afterburner range, the water control switch, item A, must be turned on and the water on light, item B, should be on to indicate water flow. Failure to use water cooling during afterburner operation causes the noise suppressor exhaust muffler to be severely damaged by the high exhaust temperature which can exceed 3000° F. In cold weather, heaters, which are controlled by switches, its E and F, on the water control box, are provided to prevent the water in the tank from freezing.

Maintaining the portable noise suppressor involves daily inspections of the batteries, tires, muffler, engine oil level and air cleaner, and the hydraulic fluid level. The 100- and 500-hours inspections are more thorough and searching inspections of the noise suppressor. Proper inspection and maintenance will keep the noise suppressor operating effectively and without major breakdowns.

Fixed noise suppressors. Figure 7-5 shows a fixed noise suppressor with an A/M37T–6C test stand. This noise suppressor can also be used with the A/M37T–20 test stand. The noise suppressor has an acoustically treated primary air silencer, item A. This type of noise suppressor can accommodate all of the airflow required for all ranges of engine operation. The engine test stand enclosure, item B, houses the thrust bed, item F, and augmenter, item C, which have provisions for a cooling water spray. This water is used to cool the exhaust plenum and silencer. The exhaust plenum and exhaust silencer, item D, provides an acoustically treated path for the high-velocity exhaust gases. Deflectors in the exhaust plenum turn the gases upwards and then releases them into the air. There are acoustical baffles inside the silencer to absorb some of the exhaust noise. The pump house, item E, contains the water pumps, fire protection CO_2 bottles, and major components of the cooling water system. All of the walls of the suppressor are filled with a fibrous acoustical mater aid in noise silencing.



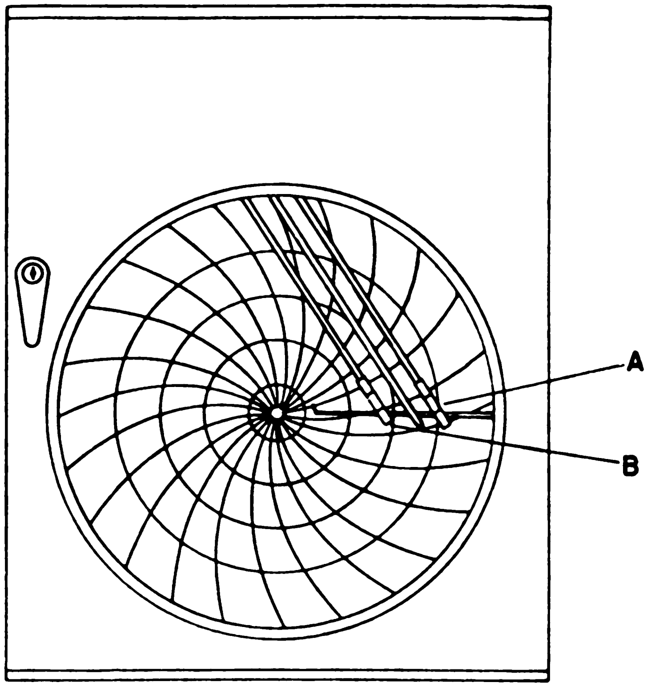
A. Primary air silencer
B. Engine test stand enclosure
C. Augmenter
D. Exhaust plenum and silencer
E. Pump house
F. Thrust bed
G. Test cell control cab
H. Auxiliary fuel tank
I. Fuel tank trailer

Figure 7–5. Fixed engine noise suppressor.

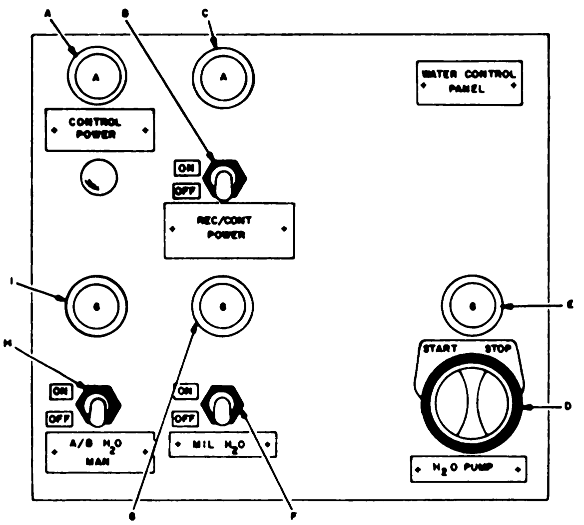
The controls for operating the noise suppressor cooling water systems are monitored in the test cell control trailer. An example of a water control panel is shown in figure 7-6. On the control is an indicator light, item A, which is on when power is on. There is a recorder control power switch, item B, and light, item C, which supplies power to the two pen recorder shown in figure 7-7. The first pen, item A, of this recorder provides a record of the rate of cooling water flow during the engine run. The second pen, item B, records the temperatures in the exhaust system during the engine run. The water pump switch, item D, is a dual button to control the start and stop of the water pump. Light E will be on whenever the start button is pushed. The military water switch, item F, and the A/B water switch, item H, open valves which allows water to flow to the diffuser in the augmentor. The indicator lights, items G and I, are on whenever power is suppllied to the control valves by the switches.

When operating an engine in the noise suppressor, all doors must be closed to provide maximum noise suppression. Cooling water is not needed at power levels up to approximately 80 percent. If an engine is to be operated above 80 percent, the military water switch must be on. When an engine is to be operated in the afterburner range, then the A/B water switch must be on.

Good inspections and maintenance on the unit will extend the life of the noise suppressor and keep it operating at peak effectiveness. At each periodic inspection, you should check all of the acoustical panels for security, cracks, or other damage. Check the water pumps, lines, and valves for operation, leaks, and wear or damage. Lubricate bearings on door rollers and pumps and check for wear. You must never operate an engine in the noise suppressor when there is a defect which could cause damage to personnel, the engine, or the suppressor itself.



A. Water flow recording pen
B. Exhaust temperature recording pen
Figure 7–7. Two pen reco.der



A. Power ON light
B. Recorder power switch
C. Recorder power switch
D. Water pump switch
E. Water On light
F. Military water switch
G. Military water light
H. A/B water switch
I. A/B water light
Figure 7–6. Water control panel

Exercises (514):

1. Explain why water is injected into the exhaust gas stream when using a noise suppressor.

2. When must water cooling be used with portable noise suppressors? With a fixed suppressor?

3. How do you operate the water system on the portable noise suppressor?

4. How do you operate the water system on the fixed noise suppressor?

5. How is noise reduced in the noise suppressors?

6. What should you do to maintain the noise suppressors?

7-2. Special Equipment

There are many items of special equipment which you, as a jet engine technician, will use in your day-to-da job. The following objectives will discuss the use and maintenance of a few of the items which are used to test, checkout, rig, or analyze a jet engine.

515. State the purpose of the Automatic Jetcal Trimmer, explain how to prevent erroneous readings, and tell how often the unit is checked.

Automatic Jetcal Engine Trimmer. The Automatic Jetcal Engine Trimmer model H119 or H119M is used to both troubleshoot the engine and adjust it during trim. The primary functions of the unit are to:

- Check for and isolate a trouble in the EGT systm.
- Permit accurate engine trimming.
- Check EGT spread.
- Check the overheat detection sensing elements.
- Check the anti-ice system.

By using the proper cables which come with the Jetcal Trimmer, you can perform all of these functions with accuracy.

Before using the Jetcal Trimmer, you must calibrate the temperature, rpm, and barometric pressure indicators. Failure to do this would cause erroneous readings during operation. To calibrate the indicators, first apply power to the unit and allow a 10-minute warmup. After warmup, calibrate each of the indicators using the CAL ADJ potentiometers. When setting barometric pressure, make sure you use the uncorrected barometric pressure for your location and not the barometric pressure which has been adjusted to sea level. After calibration is complete, you may now perform any of the checks you need to identify a malfunction or verify maintenance.

When you are done with the Jetcal Trimmer, coil all of the cables neatly and store them in the accessory case. Make sure you do not leave any of the cables or other equipment out of the case since they can be easily damaged. On a monthly basis, inspect all of the cables, connectors, and probes for broken, bent, or dirty terminals. Also, check the meters, gages, indicators, switches, and knobs for damage and freedom of movement. Repair any malfunction you have identified before allowing the unit to be used again.

Exercises (515)

1. What is the purpose of the Automatic Jetcal Engine Trimmer?

2. What is extremely important to do before using the trimmer?

3. When do you check out the unit for damage and other discrepancies?

516. State the purpose of the exhaust nozzle actuator tester and how it is maintained, determine if the exhaust nozzle area is within limits, and state how to maintain the tester.

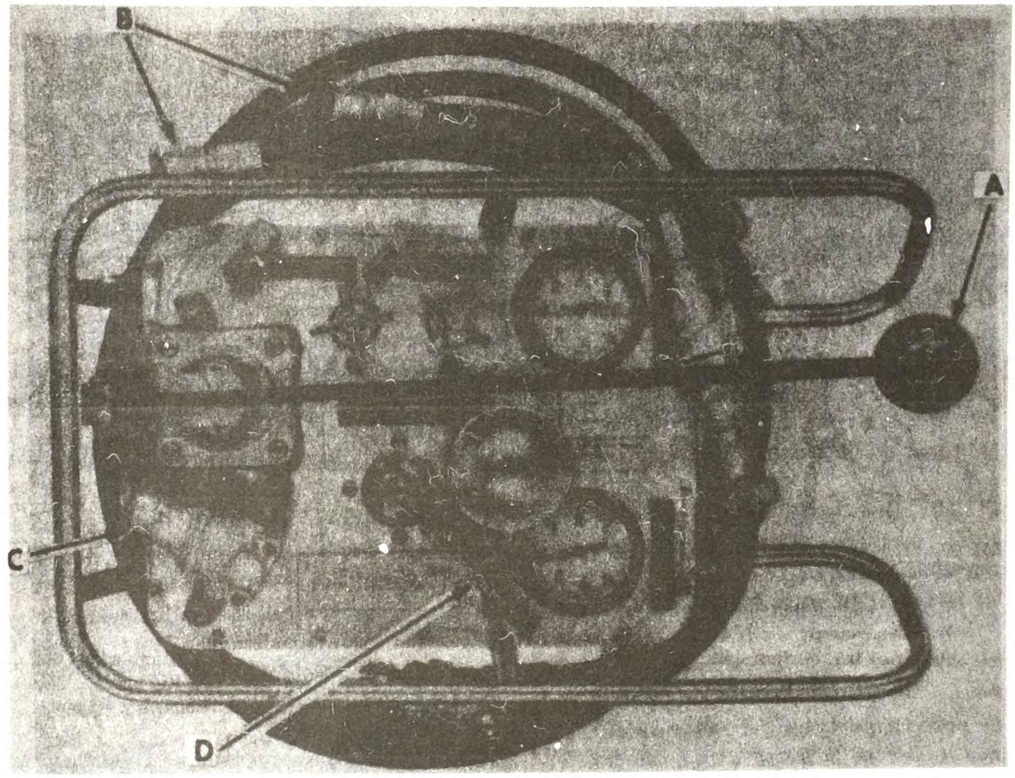
Exhaust Nozzle Actuator Tester. This tester is used on the J–79 engine to operate the variable exhaust nozzle actuators during testing, maintenance, and adjustment. The tester, figure 7-8, has a hand pump, item A, which will develop 500 psi of oil pressure to position the nozzle actuators. The tester has a 1½-gallon capacity for engine oil which is filtered before it goes to the engine. The filter, item C, has a 10-micron replaceable element. The element must be inspected weekly and changed when it is more than 50-percent contaminated.

The tester is used during the rigging of the variable nozzle feedback linkage. To adjust the linkage, you must connect the hoses, item B, to the nozzle actuator head-end and rod-end manifolds. Place the selector valve, item D, to rod end and pump the nozzle closed until the primary flap measurement is 22 5/16 +1/16 inches (see fig. 7-9). This measurement is taken from an average of four readings at different locations. Make sure that the nozzle diameter recorder (pogo stick), item A, is on the flaps and not on the seals. Failure to do this can cause erroneous readings.

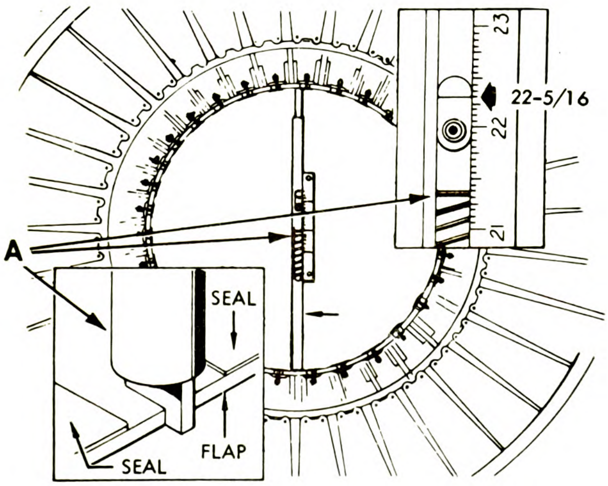
With the exhaust nozzle in the proper position, you can now raise the sheave cover, figure 7-10, item B, about 1/8 inch, and then using a 5/8-inch wrench, turn the arbor shaft, item C, clockwise until the rig pin, item A, can be inserted. Now (fig. 7-11) press the sheave cover, item B, into place with just your finger pressure while adjusting the micro-adjust unit, item A. When the cover is properly seated into place, install and torque the cover screws. Now, refer to figure 7-12. Again turn the micro-adjust unit, item A, until the rig pin, item B, can be freely removed.

Now, using the exhaust nozzle actuator tester, open the nozzle and then close it to the position shown in figure 7-9. Try to put the rig pin back into the rigging hole. If the rig pin will not freely slide into the hole, adjust the micro-adjust unit until it does.

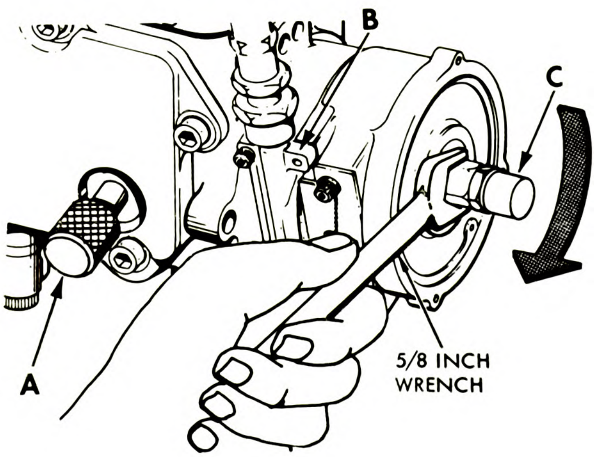
The exhaust nozzle actuator tester will help you do this job and several others. The proper care and maintenance of it will insure that it is available when you need to use it. Always make sure the hoses are not damaged and keep them capped when not in use. Check the fluid level and all valve connections for leakage. This is up to you, the user, to insure the tester does what you want it to and is ready when you need it.



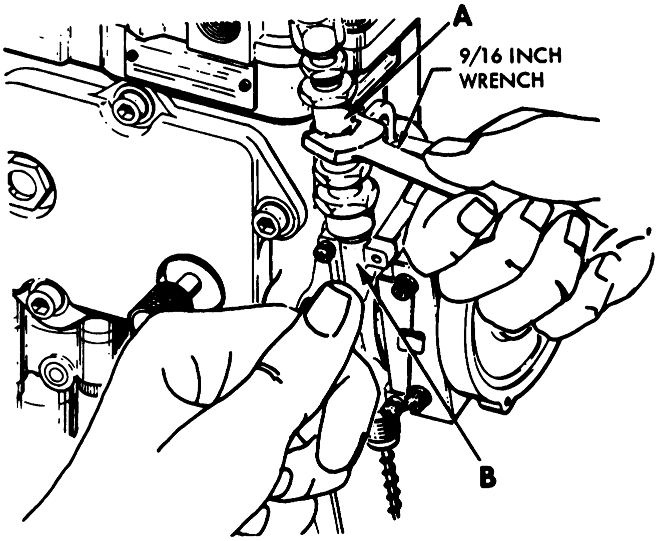
A. Pump
B. Manifold hoses
C. Filter
D. Selector valve
Figure 7–8. Exhaust nozzle tester



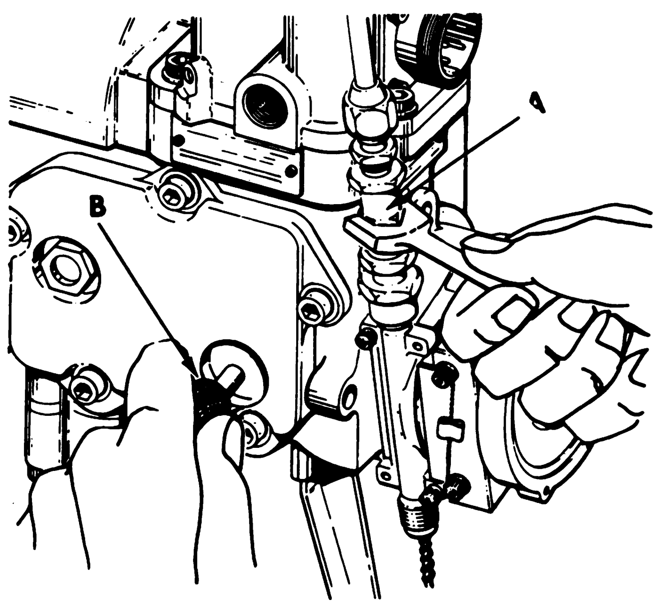
A. Nozzle diameter recorder
Figure 7–9. Exhaust nozzle measurement.



A. Rig pin
B. Sheave cover
C. Arbor shaft
Figure 7–10. Installing rig pin.



A. Micro-adjust unit
B. Sheave cover
Figure 7-11. Adjusting micro-adjust unit.



A. Micro-adjust unit
B. Rig pin
Figure 7-12. Removing rig pin.

Exercises (516):

1. How is the exhaust nozzle actuator tester used.

2. If the exhaust nozzle area readings are 22¼, 22 7/16, 22 7/16, 22¼, is this within limits? Why?

3. When checking the rigging, what do you do if the rig pin will not slide into the hole freely?

4. When do you replace the filter on the tester?

7-3. Boroscope Inspection

The use of the boroscope has been steadily increasing. Each time a new engine is designed, more provisions are made to inspect the engine with a boroscope. In the modern jet engine, almost any part which can be damaged by FOD or heat may be inspected visually through the use of either a rigid or flexible boroscope. You must be positive that your inspection is thorough and accurate. You must know what you are looking at through the boroscope and be able to determine if the engine is within serviceable limits or must be repaired. This section is written to provide you with some general knowledge of the boroscope and how to use it to inspect an engine.

The illustrations, equipment, and limits discussed in this text are not meant to be representative of any particular engine or boroscope. They are used so you can visualize what equipment is available, the general characteristics of a boroscope, and how to use it to inspect engine components.

517. State the purpose of the boroscope, and specify the limitations of the boroscope inspection.

Purpose of Boroscoping. The whole purpose of the boroscope inspection is to enable you to perform a visual inspection of the engine gas flow path. Through the use of the boroscope, you can do this without disassembling the engine and, in many cases, while the engine is still installed in the aircraft. The modern jet engine has ports which are provided to allow access to several different sections of the engine. Figures 7-13 and 7-14, show an F–100 and TF–34 engine respectively with some of the access ports identified. By using the proper boroscope you can look through these ports at the parts of the engine where damage will most likely be seen.

The boroscope inspection, while beneficial, is not intended to take the place of, or be as thorough as, a periodical teardown inspection. It is limited by the access ports available, the serviceability of the equipment, and the experience and knowledge of the person performing the inspection. Through the use of the boroscope, you can prevent many unnecessary teardowns of the engine, as well as detect minor damage which must be repaired before it causes other, more extensive, damage to the engine. The inspector must be a person of integrity who has the training, ability, and experience to know what is being seen through the boroscope and how to maneuver it to get the best view of each part of the engine.

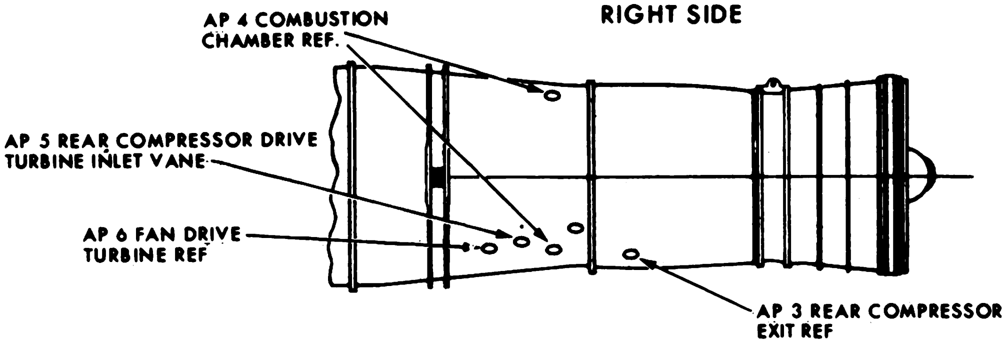


Figure 7–13. F–100 Boroscope access ports.

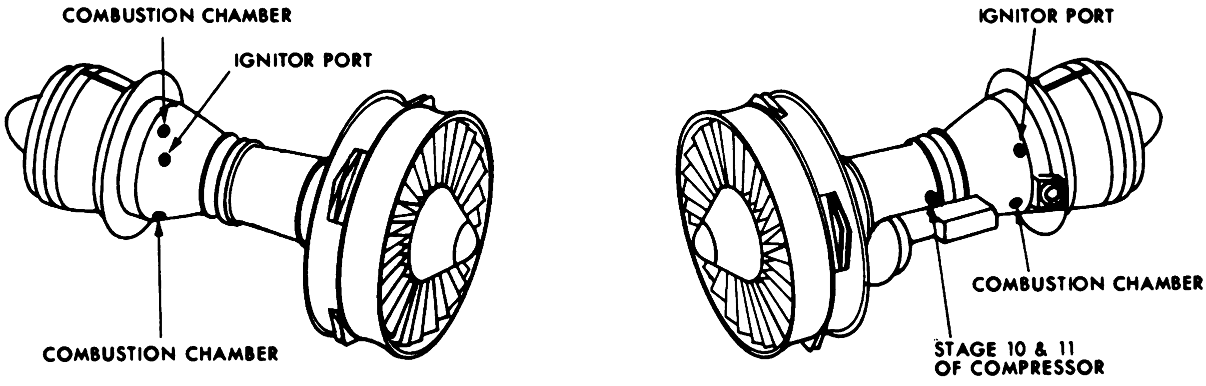


Figure 7–14. TF–34 Boroscope access ports.

Exercises (517):

1. What is the purpose of the boroscope inspection?

2. What are some of the limitations of the boroscope?

3. Which of the following would be the most desirable attributes of a boroscope inspector?

____ *a*. Experience.
____ *b*. TSgt or above.
____ *c*. Training.
____ *d*. Able to get into small places.
____ *e*. Integrity.
____ *f*. Ability.
____ *g*. Does not wear glasses.

518. Identify the two types of boroscopes, state the source of light and how it is transmitted, specify how the flexible scope is maneuvered and how the scope could become trapped inside the engine.

The Boroscope. There are several different models of boroscopes available. The one you have at your base may differ from the ones illustrated in figures 7-15 and 7-16. One is a rigid scope with a remote light source. The other is a flexible scope also with a remote light source. Both of these scopes use the modern fiber optic principle for transmitting light from the source to the end of the scope and then back to your eye.

Rigid scope. The rigid boroscope is available in varying lengths. The length of the scope you have will depend on the requirements for the engines on your base. For example, on the TF-34 engine, three scopes of 8, 12, and 27 inches in length are used. Always use the one which is the proper length for the area you are inspecting. Use of the wrong scope could cause damage to the scope itself or erroneous findings.

Flexible scope. The flexible boroscope is an optic fiber scope which allows you to see parts of the engine not visible with a rigid scope. The whole length of the scope is flexible

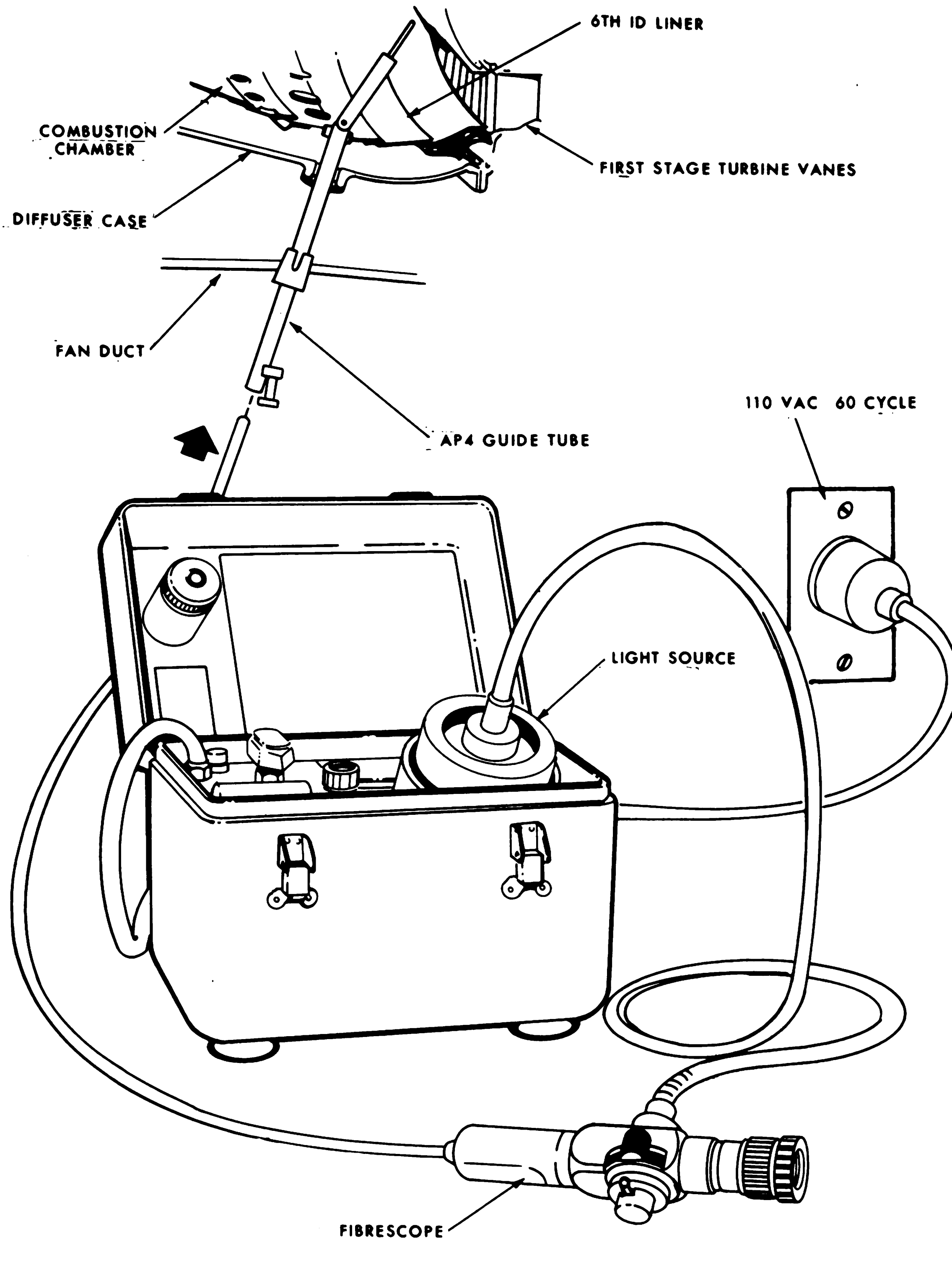


Figure 7–15. Fibrescope.

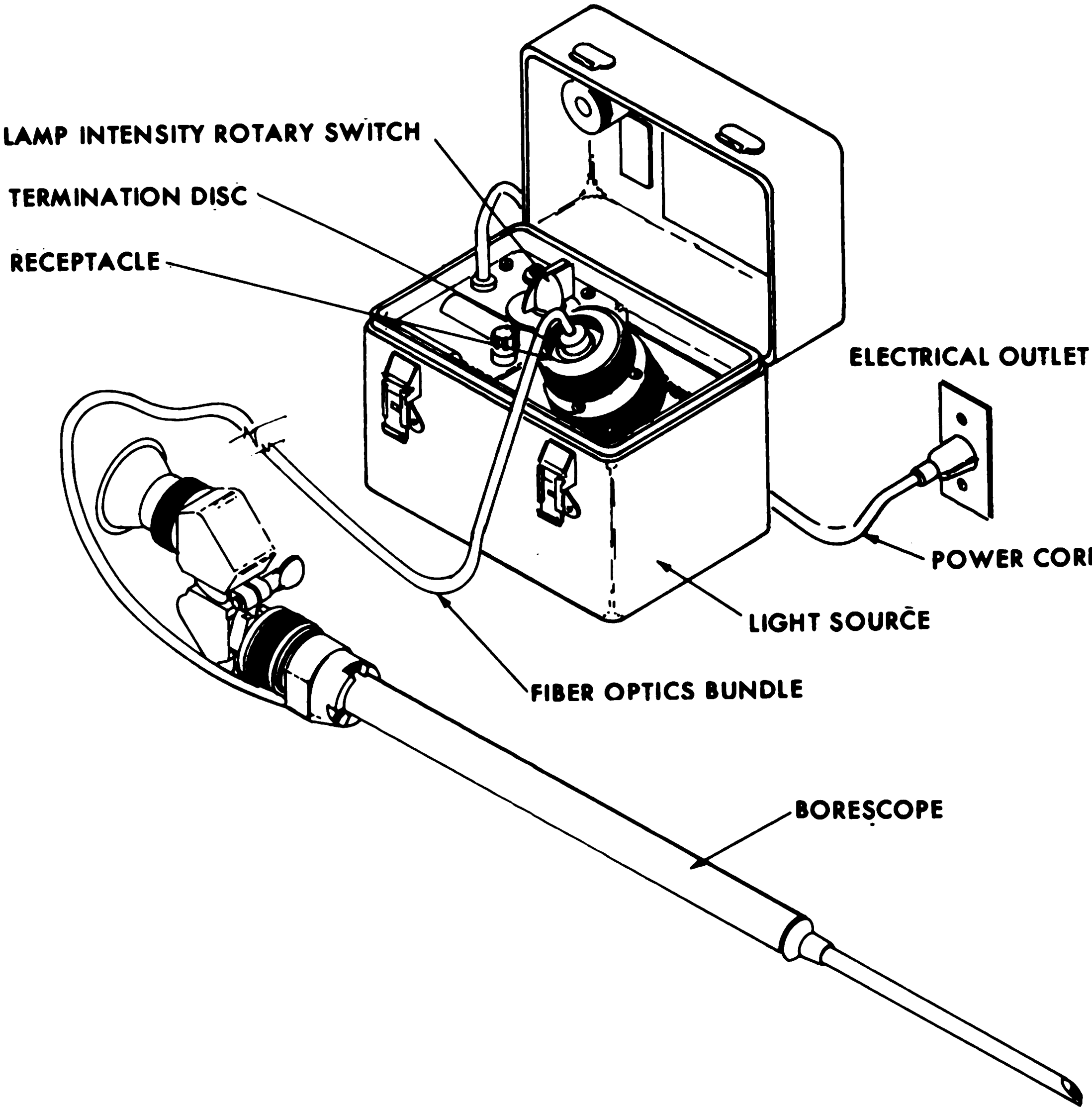


Figure 7–16. Rigid boroscope.

with a section at the tip which is controlled by a lever on the eyepiece. By properly controlling the tip, as you push the scope into the engine, you can position the tip into almost any place you want.

Figure 7-17 illustrates some positions in which the scope can be placed. Situations A and B are easy to get into and, very importantly, out of. Now look at situation C; the tip can be put into this position, but the removal would be almost impossible because of the sharp bends. When removing the scope, the bends at each pasageway will become even more acute and could actually trap the scope inside the part being inspcted. You should also be careful not to force the boroscope into a hole which is really too small for it to go into and out of easily. If either of these situations should occur inside an engine, it would most likely cause the engine to be torn down to extract the scope. When using the boroscope, you must take extreme care to insure that you do not damage the scope or the fiber optics by forcing it into or out of the engine.

Exercises (518):

1. What two types of boroscopes are used on today's engines?

2. What is used as a light source and how is it transmitted to the tip of the scope?

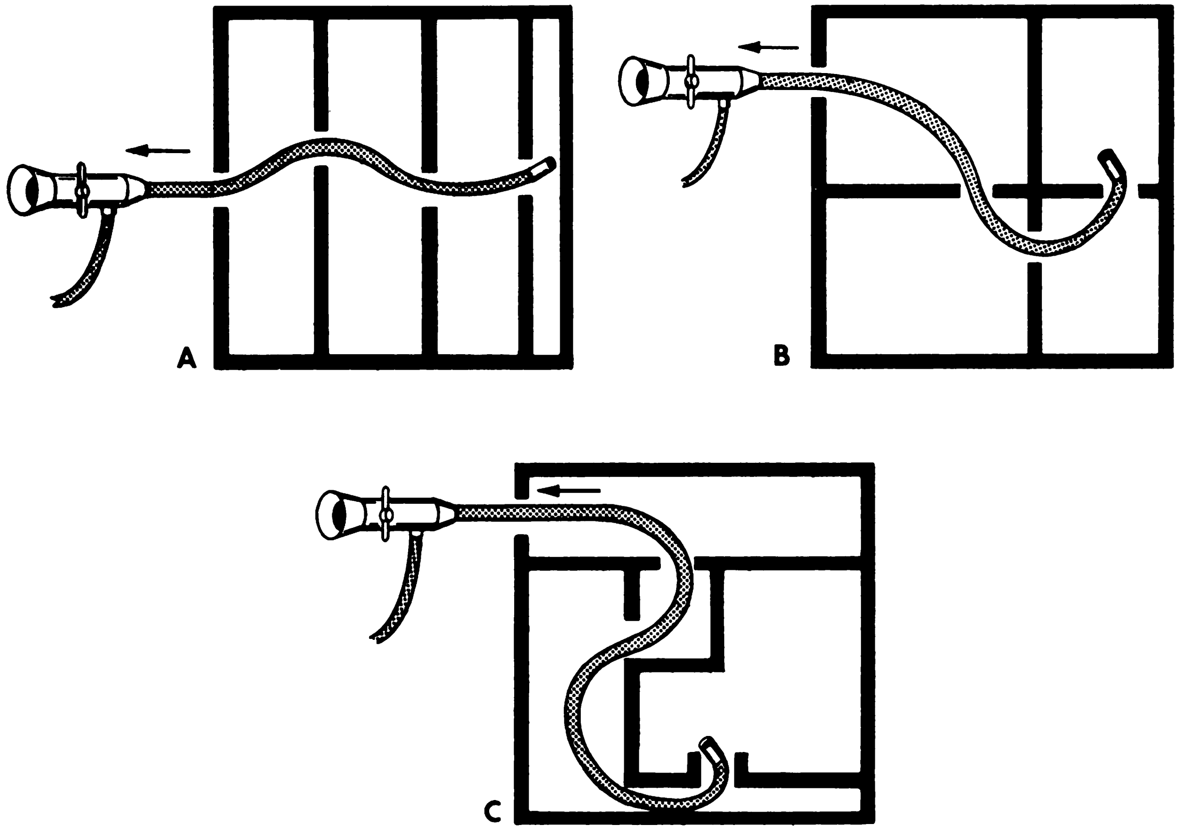


Figure 7–17. Positions a boroscope can go into.

3. How can the flexible boroscope be maneuvered inside the engine?

4. Describe what actions could cause the boroscope to become trapped?

519. Specify why the boroscope light is used on low power when it is really needed, and how to inspect the compressor rotor.

Using the Rigid Boroscope. When you are using the rigid boroscope to inspect the engine, take care to handle the unit carefully. Never turn the brightness switch to high, unless it is required for long distance viewing or photography. Using the high position more than necessary will substantially reduce the life of the bulb. Normal life is about 200 hours, but at high power this can be reduced to less than 50 hours. When the boroscope lens or either end of the fiber optic light bundle appear to be dirty, then they should be cleaned with isopropyl alcohol.

Inspecting the engine. Before you can insert the boroscope into the engine, you have to remove the access port plug. If you were going to inspect the 10th and 11th stage compressor rotor blades on the TF–34 engine, you would remove access port S15 shown in figure 7-14. To inspect these blades, you would use the rigid scope. Carefully insert the scope and adjust the depth of penetration until you can see the stage 11 blades through the scope. Figure 7-18 shows the view you should have through the boroscope at this time. Now, rotate the compressor by turning the accessory gearbox using whatever method is provided for your particular engine. Make sure that you inspect each blade for nicks, pits, scratches, dents, erosion, and wear. Check your TO for limits.

Identifying defects. During your inspection of the engine, you must determine the size of all of the defects you find. Then compare this size to the limits given in the TO. You will have to be extremely accurate in your determination because this will be used as the basis for removing an engine for teardown or retaining it in service. You might ask, 'Why is it so hard to make this accurate determination?'' The answer is that the boroscope magnifies everything from 2 to 10 times depending on the eyepiece used. For this reason, you will have to use some method to gage the size of a defect.

When you are trying to gage the size of a defect, there are at least two methods you can use. One is to use the size of an engine part which you know and compare that part to the defect. The other method, which can be used for very small defects, is to tape a long piece of 0.032-inch safety wire to

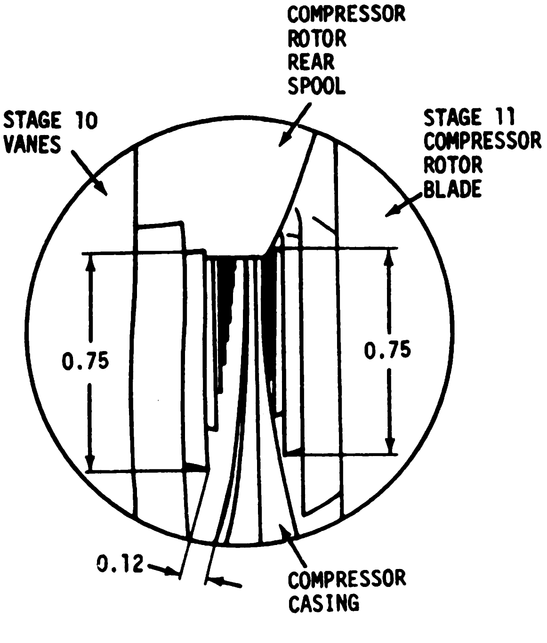


Figure 7-18. View of compressor.

the boroscope. Then, bend the wire so the end can be seen through the scope. Now, insert the scope into the engine and compare the size of the defect to the size of the safety wire.

Insuring complete inspection. When you have inspected each blade on the 11th stage, turn your scope 180°. Now, you can see the 10th stage blades by looking through the 10th stage stator vanes. After inspecting each of these blades, you are done at this access port. You have to make sure that you have inspected each blade. To do this, you can count each blade as it is inspected and when you have reached the number of blades in that stage, then you are done. Another way is to find an identifying mark on the rotor. Figure 7-19 shows an example of a mark which is found on an F-100 rotor.

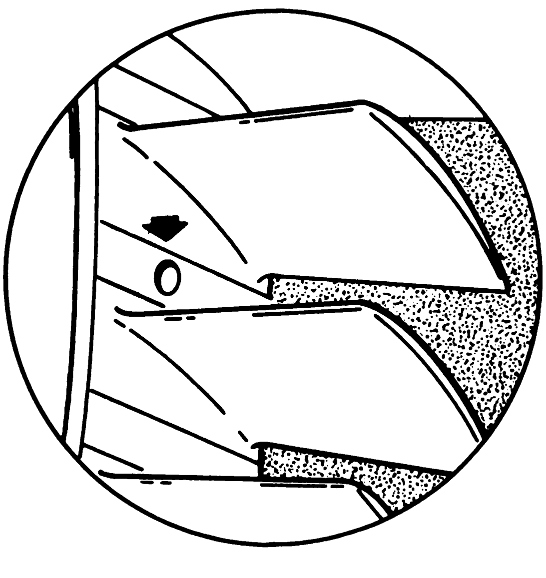


Figure 7-19. Dimple on compressor rotor.

Exercises (519):

1. What will happen if the high power position is used more than necessary on the boroscope?

2. What method is used to position each blade of a compressor rotor so it may be inspected?

3. What are two methods of insuring you have inspected each blade in a compressor stage?

4. Why is the size of a defect hard to determine when using a boroscope?

5. How can you judge the size of defects?

520. Specify what is used to inspect parts of the engine which cannot be seen with the rigid boroscope, how to adjust the flexible boroscope, and how to determine the size of cracks in the combustion section and turbine nozzle vanes.

Using the Flexible Boroscope. The flexible boroscope, like the rigid boroscope just discussed, uses a remote light source which is transmitted to the end of the scope by fiber optics. Many times it will use the same light source and fiber optic brindle as the rigid boroscope. The flexible scope is used to inspect parts of the engine which cannot be seen with the rigid scope. Since the tip is maneuverable and the whole length is flexible, it can be guided into almost any place or position you need it. Sometimes a guide tube such as the one shown in figure 7-15 is used to help position the scope at the proper angle.

Adjusting the flexible boroscope. Before you can use the flexible boroscope, you must know how to adjust it. Figure 7-20 shows how the eyepiece is adjusted. This adjustment must be made by each person who uses the boroscope since the purpose of this adjustment is to focus the image for your particular vision. To adjust the tip of the boroscope, you have to move a lever on the viewing head. Figure 7-21 shows how this adjustment is made on this model boroscope. It is extremely important that you do not force the tip adjustment. Forcing the adjustment could cause the glass fibers inside the light bundle to break. As these fibers break, the clarity and resolution of the boroscope will be reduced. Once you have the tip at the exact angle you wish, you can then lock it in place by setting the brake, which is illustrated in figure 7-22.

Performing the inspection. Once you know how to adjust the boroscope, you can begin your inspection. For example, by using access port 4 on the F-100 engine, figure 7-13, you

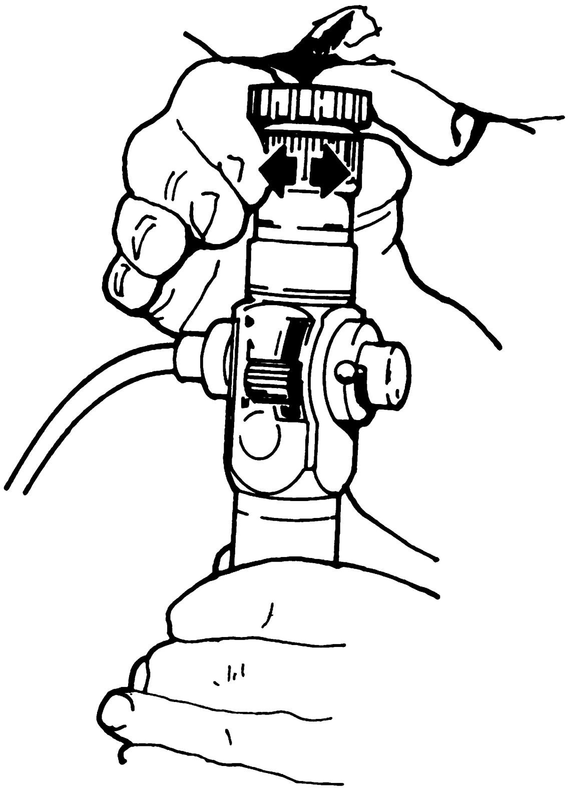


Figure 7–20. Focusing the boroscope.

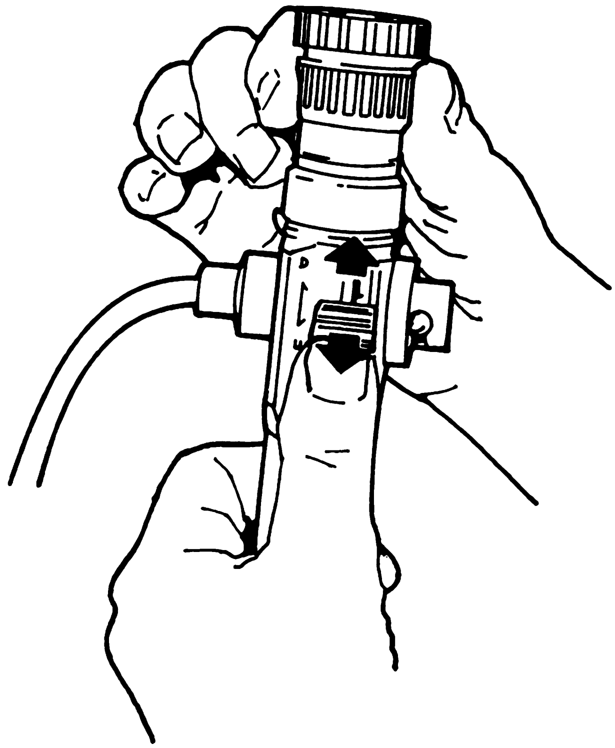


Figure 7–21. Adjusting the movable tip.

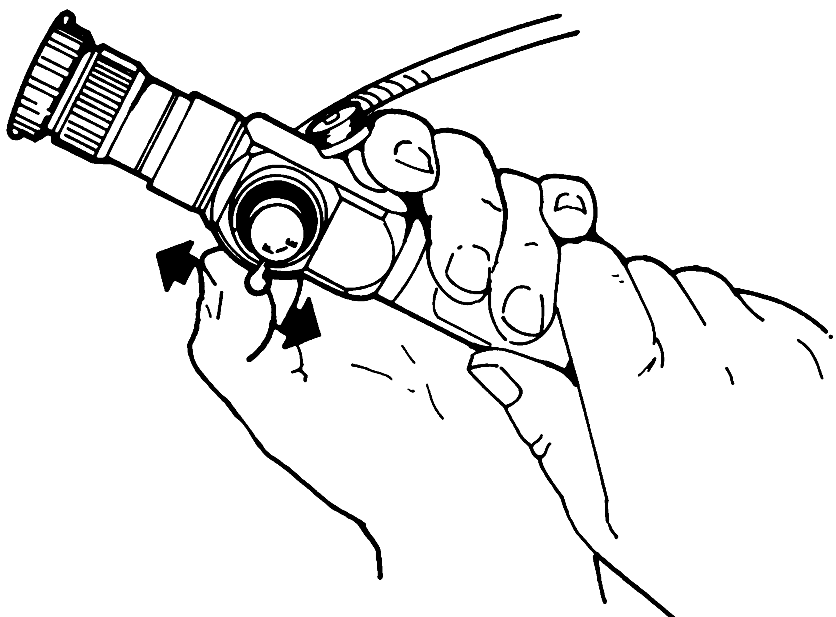
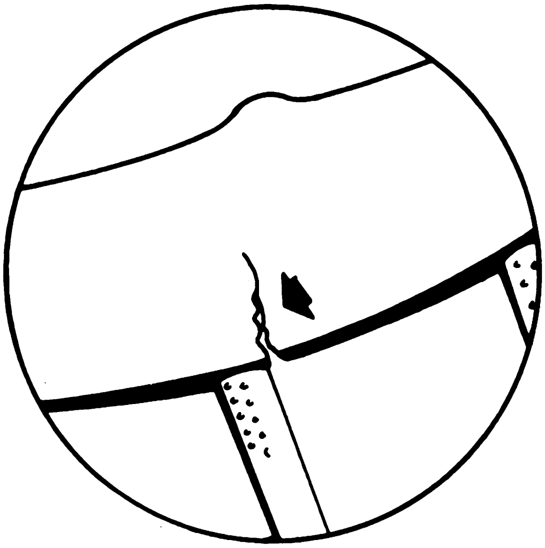
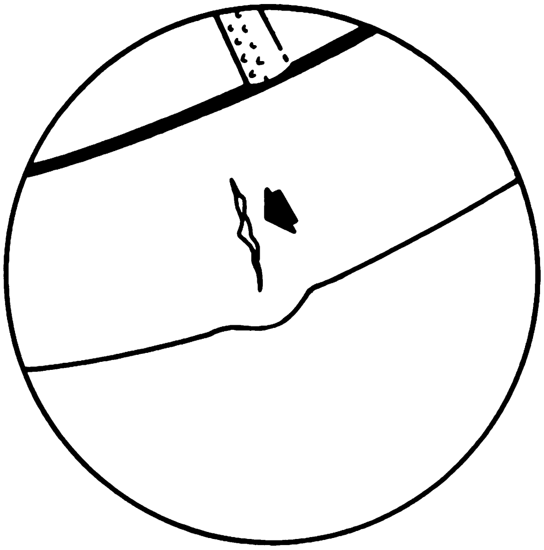


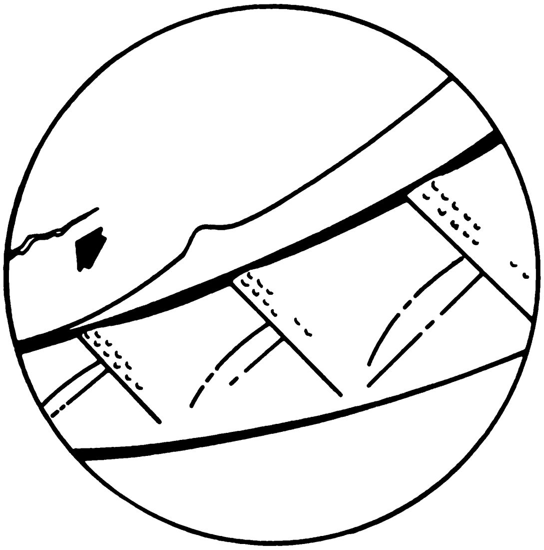
Figure 7–22. Movable tip lock.



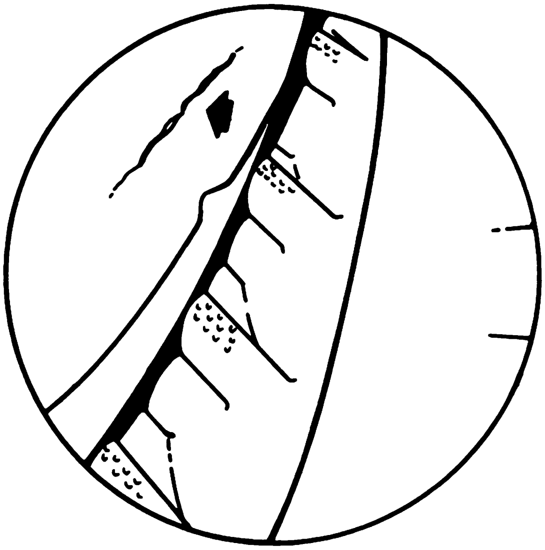
NO. 7 INNER LINER
AXIAL CRACK



NO. 7 OUTER LINER
AXIAL CRACK



NO. 6 INNER LINER
CIRCUMFERENTIAL CRACK



NO. 6 INNER LINER
CIRCUMFERENTIAL CRACK

Figure 7–23. Example of combustion chamber defects.

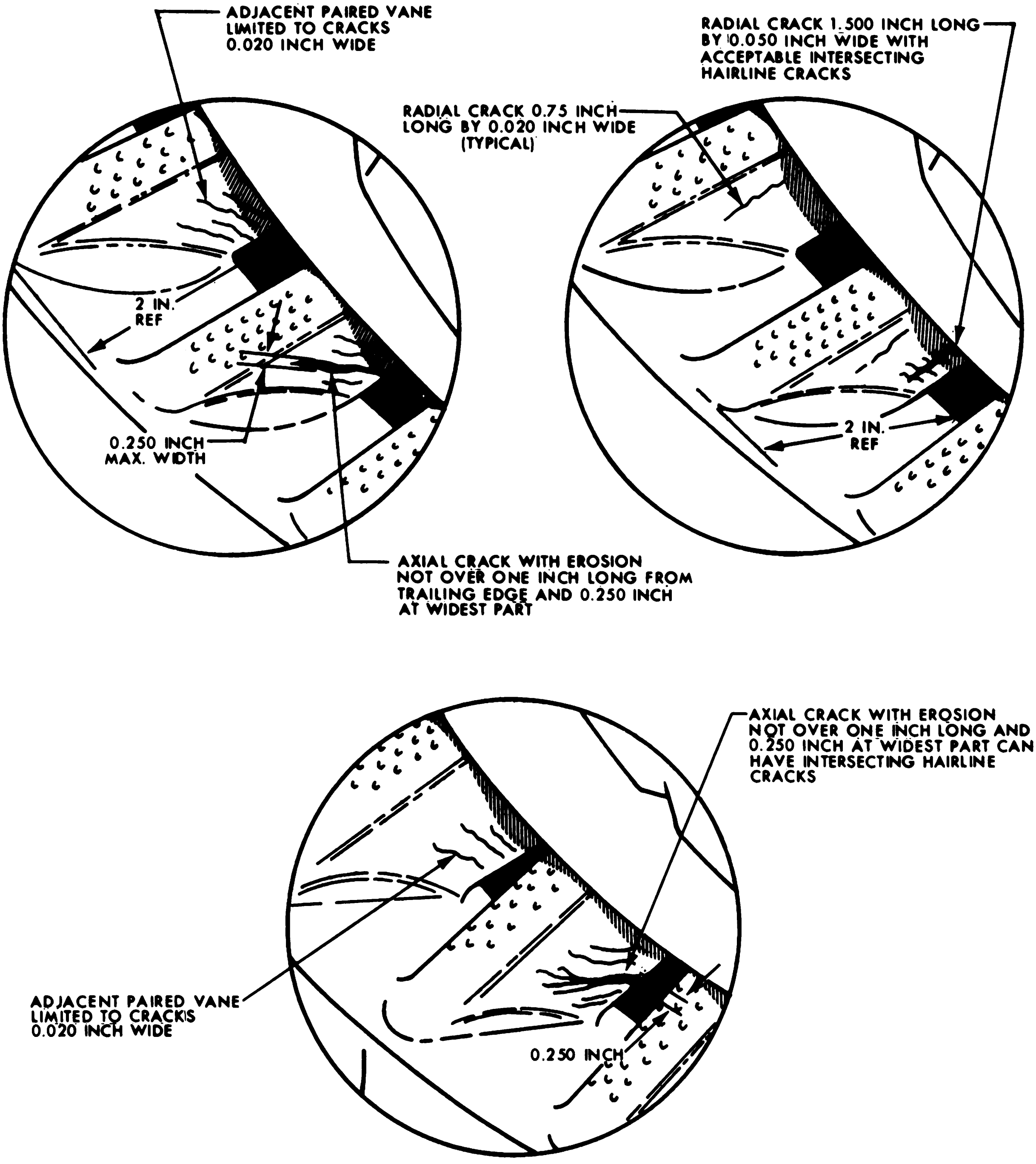


Figure 7–24. Example of turbine defects.

can inspect the combustion chamber. Some of the possible defects which you might see are shown in figure 7-23. Some cracks are allowable in the combustion chamber. In figures 7-20 and 7-21, any number of cracks are allowed, so long as none of them are over 2-inches long or over 1/8-inch wide. In figures 7-22 and 7-23, the number of cracks is not limited, but the total length of all cracks cannot exceed 20 inches.

When you are inspecting the combustion chamber, you will have to record each crack that you see. You will have to determine its size by comparing the crack to the size of some part inside the engine. You must perform a very thorough inspection to make sure you do not release an unserviceable engine.

Another area which can be inspected through access port 4 is the first stage turbine nozzle vanes. There are some defects allowed in the nozzle vanes as shown in figure 7-24. In these three views, you can see some of the defects which you might find. It also shows the reference dimensions and some of the crack limits for the vanes.

It is needless to say that we have not discussed all of the ports which can be inspected with the boroscope. By now you understand that through the proper use of a boroscope you can accurately determine whether an engine is serviceable or needs repair. Your expertise with the boroscope can save the Air Force thousands of dollars through reduced man-hours, maintenance and engine downtime. The success of the whole process depends entirely on you.

Exercises (520):

1. What should you use to inspect parts of the engine which are not reachable with the rigid boroscope?

2. What adjustments can be made on the flexible boroscope and how are they made?

3. When you see a crack in a combustion liner, how can you tell its length?

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

400 – 1. Special tools.
400 – 2. In the proper intermediate maintenance TO.
400 – 3. They could cause serious injuries.
400 – 4. Carefully. They are very expensive and hard to get.

401 – 1. Weight capacity, loose nuts or bolts, bent or damaged stand parts, and that safety pins are properly installed.
401 – 2. Engine transportation trailer model 3000.
401 – 3. No. This procedure is used to level the engine in the stand.

402 – 1. To properly support the engines on maintenance stands and transportation trailers.
402 – 2. Damage to engine parts and maintenance on the engine can become harder.

403 – 1. In the form of captions such as notes, cautions, and warnings.
403 – 2. To reduce contamination and subsequent engine failure.
403 – 3. For ease in locating defects.

404 – 1. Careless handling of tools during maintenance.
404 – 2. They should be installed over the tube end.

405 – 1. By varicolored code bands.
405 – 2. 20% of the tubing diameter.
405 – 3. .3675 inch.
405 – 4. Teflon hose assembly.

406 – 1. 20 inches.
406 – 2. It should be a duplicate of the hose which is removed as to length, outside diameter, inside diameter, material type, and contour unless otherwise directed.
406 – 3. It prevents the hose from being pulled off the end of a nipple due to engine movement.

407 – 1. Aircraft –2 series TOs.
407 – 2. (1) c; (2) e; (3) i; (4) j; (5) b; (6) f; (7) a; (8) k.

408 – 1. Lack of lubrication, shock loading, heat, and extension of minor damage such as scratches, nicks, tool marks, and improper torque. Defects may also result from the presence of foreign material.
408 – 2. Failure to correct the cause of damaged parts can result in premature failure of a new or repair part.
408 – 3. This could lead to injury or failure to complete the mission.

409 – 1. Mechanical and nondestructive.
409 – 2. This tester provides a wide variety of scales and has an insignificant effect to the usefulness of the part.
409 – 3. (1) c; (2) e; (3) b; (4) d; (5) a.

410 – 1. An interruption in a normal or regularly smooth surface configuration of a part.
410 – 2. An indication of a crack may not always be that of a significant discontinuity, a discontinuity is not always a crack, and a defect may not always be cause for rejection of a part.
410 – 3. The item must be made of ferromagnetic materials.
410 – 4. Fluorescent-coated particles are used and then viewed under a black light.
410 – 5. Fluorescent dye penetrant method.
410 – 6. No. The paint remover and dissolved paint may enter the discontinuities and prevent the entry of the penetrant.
410 – 7. Eddy current.
410 – 8. The surfaces must be smooth, flat, and very easy to get to.
410 – 9. Uses high frequency sound waves to locate and identify defects.
410 – 10. By the complexity of the part and the inspector's ability.
410 – 11. Dark areas on the film.
410 – 12. It is both very hazardous and very expensive.

411 – 1. Crocus or emery cloth.
411 – 2. Chromic acid treatment solution is extremely injurious to skin and eyes and prolonged breathing of fumes can cause respiratory trouble.

412 – 1. It should be stroked along the longitudinal axis of the blade.
412 – 2. Chalk or dye markers.

413 – 1. Improved safety, reduced maintenance costs, and increased equipment availability.
413 – 2. Improved safety comes from detecting equipment which ha a mechanical failure before it becomes a hazard. The reduced maintenance costs come from reducing failures, secondary damage, overmaintenance, and other related costs. The increased equipment availability is derived from the higher in-commission rate due to less unnecessary maintenance.

414 – 1. Base level and designated laboratories.
414 – 2. AFTO Form 2026.
414 – 3. JOAP project monitor.
414 – 4. TO 33–1–37.

415 – 1. Friction and the consequent wearing away of contacting surfaces cause small particles of metal to be removed. These metallic elements, called wear metals, may be microscopic or submicroscopic in size and carried suspended in the lubricating fluids.
415 – 2. Constant and quite low.
415 – 3. Any condition which alters the normal relationship or increases in normal friction between the moving engine parts.

416 – 1. Whether the oil has circulated in the system long enough to accumulate wear metal concentrations that will indicate the condition of the system and whether the oil sample truly represents the oil circulating in the system.
416 – 2. Oil samples should not be taken until the engine accumulates 5 hours or more after an oil change. Oil sample should not be taken immediately after oil has been added. Take the samples immediately after the engine has been operated.

417 – 1. The greater probability that incipient failures will be detected.
417 – 2. Before or after the flight will fall within the 20 percent of desired time.

418 – 1. The laboratory telephones the organization's JOAP monitor and recommends action to be taken with regard to the suspected oil sample. Telephone calls are always confirmed by a message from the laboratory with one of several possible recommendations.
418 – 2. Follow the instructions in the message from the laboratory.
418 – 3. 5 hours.

419 – 1. Whenever you suspect something is wrong with the engine or when some abnormal condition exists within the engine.
419 – 2. In order to prevent contamination and to insure that the oil samples are representative of the oil circulating in the oil system.

420 – 1. Cotton gloves.
420 – 2. Bearings should be wrapped in a greaseproof paper or a suitable substitute.

421 – 1. Drifts and backup tools.
421 – 2. The mechanic should have checked the puller flange and examined it for proper seating in the puller groove.
421 – 3. The bearing puller was not properly aligned.

422 – 1. Poor cleaning prevents adequate visual inspection.
422 – 2. (1) c; (2) a; (3) h; (4) d; (5) k; (6) i; (7) e; (8) b; (9) f; (10) a; (11) k; (12) j; (13) g.

423 – 1. To prevent overheating the parts and having sediment collect on them.
423 – 2. Thermostatically controlled.

CHAPTER 2

424 – 1. QEC kit parts.
424 – 2. Aircraft –10 TO.

425 – 1. Not to damage number 6 bearing carbon seals and spacers.
425 – 2. Yes. By V-grooving the cracks and welding.
425 – 3. By using a 6-inch steel rule along the nozzle with the end based on the oil suction pumps.

426 – 1. The odd numbered liners have female crossover tubes, the even numbered have male crossover tubes, numbers 5 and 4 have igniter plug receptacles, and number 4 has a burner pressure probe hole.
426 – 2. Number 4, the even numbers, and then the odd numbers in any sequence.

427 – 1. No. Cracks originating at the crossover tube renders it unserviceable.

428 – 1. By splines and coupling.
428 – 2. 2.

429 – 1. It directs exhaust gases to the turbine wheels at the most efficient angle.
429 – 2. Outlet duct assembly and turbine nozzle vanes.
429 – 3. On the rear flange of the turbine front bearing support.
429 – 4. Turbine nozzle inner seal, inner seal support assembly, and nozzle vanes.
429 – 5. On the outlet duct assembly.
429 – 6. Turbine nozzle case, turbine inner seal, and seal support and nozzle vanes.
429 – 7. The combustion chamber outer rear case.

430 – 1. By the N_2 coupling.
430 – 2. The outer race is in the rear compressor turbine rotor shaft and the inner race is on the outside of the front compressor drive turbine rotor shaft.

431 – 1. With the lifting bracket installed, connect the hoist and remove the four flathead screws.
431 – 2. Remove the bowed vane and replace it with a serviceable vane of the same classification. Next, correct the malfunction that caused the bowing.

432 – 1. The number 5 bearing.
432 – 2. Dents without sharp edges or corners and not over 1/4-inch deep with a maximum area of 2 square inches.

433 – 1. Install protectors on them.
433 – 2. Do not pry and handle carefully during transfer to the awaiting fixture.

434 – 1. Prior to inspection or replacement.
434 – 2. Protective goggles.

435 – 1. A stiff bristle brush or a brass or copper fine wire brush.
435 – 2. Replace the individual fuel nozzles.

436 – 1. Molykote Type Z and compounded oil.
436 – 2. Cut grooves in the heat shield and heli-arc weld it with a tungsten electrode.

437 – 1. Avoid distortion by careful handling.
437 – 2. Freon.
437 – 3. Block off the nozzles with special designed caps and apply Freon gas pressures.

438 – 1. When the bearing or N_2 compressor is replaced.
438 – 2. A retaining nut with a rivet to secure the nut.
438 – 3. Remove the circle of nuts on the inner diffuser case, the screws holding the compressor case to outer diffuser cases, and lift the diffuser case from the compressor.

439 – 1. Yes. 5/32 inch in area C.
439 – 2. No. No cracks are allowed on the hub.

440 – 1. By washing them in kerosene or by petroleum solvent spray and blowing dry with air.
440 – 2. Yes. 25% of the sealing face remaining is serviceable.

441 – 1. Heat the inner race in hot oil and secure it on the shaft with the retaining nut. Chill the outer race and position on the shaft with serial number forward.
441 – 2. The intermediate case to the front compressor case and then the compressor diffuser case.
441 – 3. A snapring.

442 – 1. On the rear hub of the N_1 compressor.
442 – 2. Incorrect oil jet installation, causing the bearing to heat and fail.

443 – 1. To make sure the bearing is positioned correctly.
443 – 2. To make sure the bearing is concentric with the engine.

444 – 1. Apply a thin coating of seal compound to the flanges, install a new gasket and bolts, and torque properly.
444 – 2. Apply antiseize compound to the outer race, drift on, secure with spanner nut, and install two rivets 180° apart.
444 – 3. The turbine front bearing support.

445 – 1. Loading pusher tool and depth micrometer.
445 – 2. With loading pusher tool, apply 1000 + 50 pounds of pressure, take readings with depth micrometer at 3, 6, 9, and 12 o'clock positions, and average the readings.

446 – 1. With bolts and nuts and with the boltheads to the rear and safetywire.
446 – 2. Index marks on the outer diameter of the nozzle assemblies.

447 – 1. The number 4½ bearing.
447 – 2. On the threaded surface inside the number 6 bearing hub.

448 – 1. Antiseize compound.
448 – 2. Be careful not to damage the combustion chamber at pressure nozzle.

449 – 1. Apply petrolatum to the number 6 bearing inner race and rotate the front compressor drive turbine rotor while installing the turbine exhaust case.
449 – 2. The number 4½ bearing oil nozzle is in the center of the oil tube and shield and number 6 bearing oil nozzle is in the sump weldment.

450 – 1. Because a failure in the gearbox could also cause damage to the engine bearing.
450 – 2. No, not as is. The nick must be honed out and care must be taken not to cause excessive backlash.
450 – 3. Replace the drive spline.

451 – 1. Contamination from the failed engine could be passed to the new engine.
451 – 2. Check the drive spline for excessive wear; the plumbing and electrical connections for damage, security, and condition.
451 – 3. Condition.

452 – 1. None.

452 – 2. a, b, c.

452 – 3. In the fan reverser, discharge air to be directed into the intake of the adjacent engine. In the aft reversers, reduce efficiency of the reverser.

452 – 4. Make sure the reverser does not move to the reverse position while the engine is at too high a speed.

CHAPTER 3

453 – 1. It acts as a receiver of compressor discharge air, an enclosure for the combustion liner and torus, and as a cool encasement of the hot turbine.

453 – 2. The top of the combustion liner is attached to the combustion cap by the fuel atomizer mounting screws and then clamped to the turbine plenum and the discharge end slips into the torus.

453 – 3. The turbine plenum drain valve.

453 – 4. (1) b; (2) e; (3) h; (4) a; (5) c; (6) d; (7) f; (8) g; (9) e; (10) d; (11) e.

454 – 1. The differential air pressure regulator, unloading air shutoff valve, thermocouple, thermostat, turbine flange, fuel atomizer, igniter plug, and combustion chamber.

454 – 2. Acceptable, B, C, F, G: unacceptable; A, D, E.

454 – 3. No. Any evidence of burrs on the orifice plates is cause for rejection of the plates.

455 – 1. It is threaded to the aft end of the turbine nozzle.

455 – 2. With left-handed threads.

455 – 3. Attaching nuts.

456 – 1. All B–1 accessories and the engine accessory section.

456 – 2. Holding stand.

457 – 1. Tab lock.

457 – 2. The surface is very critical.

457 – 3. The shaft and wheel must be replaced.

457 – 4. None. Nozzle is serviceable with a crack of this length.

457 – 5. None, so long as the dents are less than 1/16 inch in depth.

458 – 1. To mount and drive the engine and customer accessories at a useable rpm.

458 – 2. Centrifugal switch, oil pump, tachometer generator, starter, fuel pump and control unit.

458 – 3. The quill shaft.

459 – 1. The front end of the compressor.

459 – 2. By pressure oil.

459 – 3. The interstage ducts.

459 – 4. 50%.

460 – 1. Number 1 bearing, in the compressor assembly, number 2 bearing, on the turbine shaft.

460 – 2. The compressor assembly would have to be returned to the depot for repair.

461 – 1. In the table of limits.

461 – 2. Yes, but you should try to obtain a reading of 0.0005 inch.

461 – 3. Disassemble the parts and rotate the spacer or the impellers 120°.

461 – 4. The turbine wheel to shroud clearance is too small.

461 – 5. There is not enough room to properly stack the rest of the engine.

461 – 6. Adjust the shim thickness to obtain the correct measurement.

462 – 1. Replace the bolt, nut, or washer.

462 – 2. 120 inch-pounds.

463 – 1. The first unit should be between the 3 and 6 o'clock positions and the second unit should be between the 9 and 12 o'clock positions.

463 – 2. Clockwise direction.

463 – 3. Counterclockwise direction.

463 – 4. 3.

464 – 1. To never reuse a cotter pin.

464 – 2. A checknut uses friction between metal and lockwashers exert a spring pressure.

CHAPTER 4

465 – 1. To check the quality of the maintenance work performed and to determine if the engine and its associated parts are serviceable.

465 – 2. Runup, thrust, and trim check.

465 – 3. The functional acceptance test.

465 – 4. To determine the engine condition prior to scheduled maintenance.

466 – 1. It may be adjusted and system troubles may be analyzed without extensive aircraft downtime. In addition, there is a saving in work hours during engine changes.

466 – 2. Systems and units may be tested to assure trouble-free operation. Preliminary engine trim can be made, eliminating excessive operation following engine installations. Maintenance operations such as field cleaning and EGT spread check may be accomplished.

467 – 1. (1) a, b, e, (2) f; (3) c, d; (4) l, (5) g, h; (6) j; (7) i.

468 – 1. 1–17 on the switch scale.

468 – 2. DIGITAL

468 – 3. Range 1: 0 to 750.00 pph; range 2: 0 to 7500.0 pph range 3: 0 to 75000 pph.

469 – 1. Engine rotor speeds up to 70,000 rpm.

469 – 2. Has a big effect on the accuracy of the digital indication.

469 – 3. Inlet air, anti-icing, fuel, and lube oil iron-constantan.

469 – 4. Place analog/digital switch to DIGITAL.

470 – 1. Check the AFTO Form 244 for any discrepancies; visually inspect the entire unit for loose wiring, leaks, loose components; and that the fuel and oil systems have been serviced.

470 – 2. No. EGT temporarily should swing into the red zone.

471 – 1. Check AFTO Form 244 for discrepancies; and check unit for loose electrical connections, detached or loose components, leaks, and proper fuel and oil level.

471 – 2. The DC connector is oval and the AC connector is rectangular.

472 – 1. Forced vibration and externally excited vibration.

472 – 2.
a. Cycles completed in a given time.
b. One-half the displacement from the axis.
c. Unit of measurement of vibration (0.001-inch movement).
d. Stage of progress of the cycle.
e. Angular lag between the actual heavy spot and the place around the rotating part.
f. When the frequency of forced vibration is the same as the natural frequency of the body.

473 – 1. Displacement may be the same with variance in parameters.

473 – 2. Vibration characteristic.

474 – 1. To determine which specific part or unit of the engine is vibrating.

474 – 2. B 4.

474 – 3. (1) d; (2) i; (3) e; (4) m; (5) k; (6) o; (7) f; (8) l; (9) g; (10) j; (11) c; (12) a; (13) h.

475 – 1. To find actual rpm of an engine.

475 – 2. 8730 rpm.

475 – 3. 92%.

476 – 1. It is a smaller increment of rpm to pinpoint the exact source of vibration.

476 – 2. 97 cps.

477 – 1. If analyzer is tuned to the exact part causing the vibration it will stay tuned throughout all power ranges.

477 – 2. .7857.

478 – 1. It is used to identify the vibrating accessory by computing gear speeds.478 – 2. .433.

479 – 1. a. 6532; b. 108.8; c. 1.83.

480 – 1. Make sure rail adapters are compatible and secure the upper and lower rails of the thrust bed.

480 – 2. To support and secure the engine under test to the thrust trailer.

481 – 1. All miscellaneous loose equipment for the test stand except the fuel hose.

481 – 2. The inventory step.

482 – 1. In reverse of the installation sequence.
482 – 2. In reverse of the installation sequence.

483 – 1. An effective inspection program.
483 – 2. Technical data with local options.

484 – 1. Service and periodic.
484 – 2. On a specified number of calendar days, depending on average use.

CHAPTER 5

485 – 1. Take time to observe the safety precautions set forth in safety manuals published by the Air Force and civilian agencies.
485 – 2. The air intake of most jet engines can develop enough suction to pull a person up to or partially into it.
485 – 3. Wear asbestos gloves.
485 – 4. 4000 Hz.
485 – 5. High temperature, high velocity, toxicity, and flames.

486 – 1. Spin the engine compressor by means of the starter. This cools the engine in the vicinity of the fire and clears out both the fuel and the fire.
486 – 2. Thermal shock or engine seizure due to contractions.
486 – 3. Turn off everything except the starter and keep the compressor turning until the fire is out.

487 – 1. The airman will show symptoms of pain, a feeling of fullness, ringing or burning of the ears, sometimes dizziness, impairment of mental concentration, and occasionally nausea, vomiting, or weakness of the knees.
487 – 2. Earplugs and ear muffs or headsets.

488 – 1. Expensive repair or replacement of parts or complete engine.
488 – 2. During the prerun and postrun inspection.

489 – 1. To tell if any conditions exist that may be unknown to you.
489 – 2. No. The engine must be completely assembled and each part properly torqued prior to the test run.

490 – 1. Check for full travel over the complete power range and be sure it is properly secured.
490 – 2. Be sure no loose objects are present and service CSD and hydraulic pumps with proper fluid to required level.

491 – 1. With power applied, press the ignition test switch and have an observer listen beside the combustion section for a steady snapping.
491 – 2. Proper servicing, FOD, freedom of compressor rotation, and engine and engine dolly mount security.
491 – 3. Apply fuel pressure, motor engine, and carefully check for leaks.

492 – 1. Beware of excessive heat at the exhaust section and relight after shutdown.
492 – 2. Check for leaks and security of engine components.
492 – 3. Check to be sure all pressure and power switches are off, including air-conditioning; inspect thrust bed, leads, and hoses; and service all systems.

493 – 1. To provide a record of the engine test and prove that the engine was subjected to prescribed test procedures.
493 – 2. Engine type and model, date, serial number, work order number, station, organization, and data plate rpm.

494 – 1. 74.9 inches hg.
494 – 2. The operator signs for accuracy and a qualified inspector signs to varify that the annotation is correct.
494 – 3. 96.56%.

495 – 1. Because they are preset by the factory.
495 – 2. Send the part to the authorized depot for flow checking and resealing.

496 – 1. Adjust MAX rpm.
496 – 2. The oil pressure relief valve.

497 – 1. To reduce the downtime of aircraft, conserve spare parts, and better use man-hours.
497 – 2. To know all the surrounding facts for efficient analysis.

498 – 1. To determine the condition of the engine from instrument readings.
498 – 2. By Pt5, Pt7, or EPR.

499 – 1. Damaged oil seals within the engine.
499 – 2. It exceeds the hourly increase in consumption by 2 pounds.

500 – 1. The left one should close at 4920 to 5110 N_1 rpm. The right one should close at 5420 to 5610 N_1 rpm.
500 – 2. Replace the bleed valve governor.

CHAPTER 6

501 – 1. Aid in isolation and detection of causes of malfunctions.
501 – 2. B schedule. Since the average monthly hours is 71.5, the closest increment is 50 hours or B schedule.
501 – 3. *a.* Proper fluid level and low or dead cells.
b. Thermocouple for accuracy and duct flanges for nicks or other physical damage.
c. Evidence of damage.

502 – 1. Both the fuel pump and control could be damaged.
502 – 2. The operator is positioned at the console looking at the exhaust pipe and drawbar.
502 – 3. MIL–L–7808 and MIL–0–6081, grade 1010.
502 – 4. 2.45 gallons.

503 – 1. In the intermediate maintenance TO.
503 – 2. The hoisting boom.
503 – 3. 85–12.
503 – 4. Control box connectors, the HR–3 relay connectors, and the low oil pressure sequencing switch.
503 – 5. From the top of the accessory gear case.
503 – 6. To observe the polarity marks on the terminals and harness.
503 – 7. One end is attached to the coupling and the other end is attached to the fuel inlet of the fuel pump and control unit.

504 – 1. Whenever engine bearings, seals, or internal components are replaced.
504 – 2. During acceleration and deceleration of the engine.
504 – 3. When an air bleed load is applied to the engine.
504 – 4. A vibration check.

505 – 1. It assures that the testing equipment and engine components are properly functioning prior to engine operation.
505 – 2. Black (and) red.
505 – 3. To isolate the specific components.
505 – 4. (1) f; (2) h; (3) b, c, d, e, and g; (4) f; (5) f; (6) a; (7) f.

506 – 1. 1 minute on and 4 minutes off.
506 – 2. Fuel should flow free of bubbles.
506 – 3. 60 seconds.

507 – 1. The intake should be thoroughly inspected for any foreign matter.
507 – 2. Eye, nose, and throat irritation.
507 – 3. Asbestos gloves.
507 – 4. Washed with soap and water.

508 – 1. Temperature gradient and thermal stresses across the turbine wheel are lessened.
508 – 2. Functional check and performance check.
508 – 3. Low oil pressure light, starter cutout light, HR–3 CKT light, HR–2 relay light, 35-percent switch light, motor rotate light, 110-percent switch light, HR–1 relay light, and the HR–1 CKT light.
508 – 4. The 95-percent switch.
508 – 5. Pulling in.

509 – 1. (1) Complete, accurate, neat, and legible.
509 – 2. Date, engine serial number, temperature wet and dry barometric pressure, and engine start and stop time.
509 – 3. The scavenge pump.
509 – 4. The minimum acceptable performance of the engine and the actual performance.
509 – 5. You should have checked the Rejected block and signed your name in the Operator's block. In the Remarks section of the test log, you should have entered engine vibration excessive.

510 – 1. Speed and acceleration control.
510 – 2. (1) b; (2) a; (3) c; (4) a; (5) a; (6) c; (7) b; (8) a.

511 – 1. The oil pump assembly.
511 – 2. The oil pressure relief valve.
511 – 3. The oil pump.
511 – 4. Clockwise.

512 – 1. To control the supply of low-pressure air from the unit to the aircraft pneumatic system.
512 – 2. Differential pressure regulator.
512 – 3. Rate control valve.
512 – 4. By turning the slotted screw clockwise or counterclockwise.
512 – 5. The load control thermostat controls the exhaust gas temperature during loading.
512 – 6. By placing shims in the thermostat body.

CHAPTER 7

513 – 1. To maintain good community relations and protect the environment and your mechanic's hearing.
513 – 2. Align aircraft in suppressor with main and nose wheel guides. Install primary air silencers and pressurize seal. Close retractable door on exhaust silencer and pressurize seal.
513 – 3. Severe damage can be done to the diffuser by the heat of the engine exhaust.
513 – 4. To operate the water control panel.
513 – 5. By indicator lights and the two pen recorder.

514 – 1. The water is used to cool the exhaust muffler to prevent damage by the high-exhaust temperature.
514 – 2. On portable noise suppressors, water is used only when the engine is operated in the afterburner range. On a fixed noise suppressor, water is requireg at engine speeds above 80%.
514 – 3. Start the gasoline engine to pressurize the water system and turn on the water control switch.
514 – 4. Turn on the pumps and open the valves to the diffuser.
514 – 5. By providing an acoustically treated path for the high-velocity gases.
514 – 6. By accomplishing good inspections and never operating an engine in a suppressor with a defect which can cause damage.

515 – 1. To troubleshoot the engine and adjust it during trim.
515 – 2. Calibrate the temperature, rpm, and barometric pressure indicators.
515 – 3. Monthly.

516 – 1. To open and close the J-79 engine exhaust nozzle for testing, maintenance, and adjustment.
516 – 2. No. Because the average is greater than 22⅝₁₆ inches.
516 – 3. Adjust the micro-adjust unit until it does.
516 – 4. When it is more than 50-percent contaminated.

517 – 1. To perform a visual inspection of the engine gas flow path without having to disassemble the engine.
517 – 2. Access ports available, serviceability of the equipment, and the experience and knowledge of the person performing the inspection.
517 – 3. a, c, e, and f.

518 – 1. Rigid and flexible.
518 – 2. A remote light source which is transmitted by fiber optics.
518 – 3. With a flexible tip which is controlled by a lever on the eyepiece.
518 – 4. Forcing the boroscope through too sharp of an angle or through a hole which is too small for it.

519 – 1. The life of the bulb will be shortened.
519 – 2. Rotate the compressor by turning the accessory gearbox using the method provided.
519 – 3. Counting the blades and finding an identifying mark.
519 – 4. The boroscope magnifies everything from 2 to 10 times.
519 – 5. Compare the size of the defect against the size of an engine part or tape a piece of 0.032 safety wire to the scope and compare the defect against the safety wire.

520 – 1. The flexible boroscope.
520 – 2. The focus is adjusted by turning the focus knob on the eyepiece. The flexible tip is adjusted by moving the lever on the viewing head.
520 – 3. By comparing it to size a part inside the engine.

1984-544-008/2465 AUGAFS,AL(850044)2300

1. Thermocouple lead
2. Air shutoff valve
3. Control box connector
4. Engine oil vent
5. Oil vent hose assembly
6. Bracket
7. Control box
8. Control box connector
9. Low oil pressure sequencing switch
10. Starter motor
11. Tee
12. Oil pressure sensing hose assembly
13. Accessory case pressure hose assembly
14. Pressure sensing tap
15. Accessory case pressure port
16. Oil pump assembly
17. Hoisting boom
18. Valve control box assembly
19. Analyzer test panel
20. Test stand
21. Slide mount
22. Oil to engine hose assembly
23. Pin
24. Third point support
25. Starter harness
26. Relay connector
27. Main side mount
28. Vee clamp assembly
29. Eyebolt
30. Engine side mount
31. Thermocouple lead receptacle
32. Exhaust duct
33. Starter harness receptacle
34. Battery compartment
35. Adapter cable receptacle
36. Adapter cable
37. Test stand frame
38. Oil pressure connection
39. Fuel pressure connection
40. Control air connection
41. Accessory case pressure connection
42. Fuel Pressure sensing hose assembly
43. Control air pressure sensing hose assembly
44. Oil vent connection
45. Fuel outlet connection
46. Oil to engine connection
47. Oil return hose assembly
48. Oil return connection
49. Fuel supply hose assembly
50. Oil fitting
51. Control air line
52. Union
53. Fuel pump and control unit
54. Fuel pressure sensing port
55. Fuel inlet connection
56. Acceleration limiter valve adjusting screw
57. Tee
58. Oil pressure sequencing switch electrical connector
59. Clamp
60. Duct assembly
61. Clamp
62. Valve

Figure 2, Test Stand Analyzer Panel

1. Accessory case pressure indicator
2. Exhaust gas temperature indicator
3. Tachometer indicator
4. Load light
5. Low oil pressure light
6. Control air pressure indicator
7. Fuel pressure indicator
8. Oil pressure indicator
9. Oil temperature indicator
10. Power on light
11. Boost pump light
12. Manual speed control valve
13. Stop switch
14. Master switch
15. Boost pump switch
16. Start switch
17. Circuit breaker
18. #5 AUX light
19. Load light
20. HR-3 relay light
21. Fuel light
22. Ignition light
23. Starter cutout light
24. HR-3 CKT light
25. HR-2 relay light
26. 35% switch light
27. Motor rotate light
28. 110% switch light
29. HR-1 relay light
30. HR-1 CKT light
31. Load switch
32. HR-3 relay switch
33. Fuel switch
34. Ignition switch
35. Starter cutout switch
36. HR-3 CKT switch
37. HR-2 relay switch
38. 35% switch switch
39. Motor rotate switch
40. 110% switch switch
41. HR-1 relay switch
42. HR-1 CKT switch
43. Load jack
44. HR-3 relay jack
45. Fuel jack
46. Ignition jack
47. Starter cutout jack
48. HR-2 relay jack
49. HR-1 relay jack
50. +24V DC jack
51. -24V DC jack
52. ON-OFF switch

Foldout 1. Trailer Mounted Universal Gas Turbine Engine Test Stand Assembly.

SMALL GAS TURBINE TEST LOG — DATE: 19 NOV 80

ENGINE SERIAL NUMBER	TEMPERATURE WET	TEMPERATURE DRY	BAROMETRIC PRESSURE	ENGINE TIME START	ENGINE TIME STOP
P30863		59°F	29.50	0800	0900

RUN IN	1ST RUN UNIT	1ST RUN TEST	2D RUN UNIT	2D RUN TEST
Maximum E. G. T	1260°F	682°C	1260°F	682°C
Unload E. G. T	590°F	310°C	590°F	310°C
Maximum Fuel Pressure	210		210	
Fuel Control Air Pressure	42		42	
Vibration	0.7		0.7	
Oil Pressure Set	75		95	
Bleed Air Output @ 45°	37 PSIG		37 PSIG	
Oil Temperature	55°C		55°C	
Accessory Case Pressure	-15		-15	
Cracking Pressure	44 PSIG		44 PSIG	

ACCESSORY ADJUSTMENT	BEFORE ADJUSTMENT	FINAL CHECK
35% Switch Set	15,400	15,400
95% Switch Set	36,500	38,500
110% Switch Set	43,700	44,100
Maximum Governor Set	42,800	42,800
Minimum Governor Set	40,000	40,000
Acceleration Set	670°C	682°C
Load Control Set	660°C	660°C
Thermal Switch Set	650°C	640°C
Rate Control Set	7 SEC	7 SEC
Opening Rate	7 SEC	7 SEC
Breather Pressure		
SOAP Sample Taken	☒ YES	☐ NO

PERFORMANCE	TEST
Valve Angle	55°
Air Flow Pressure	35 PSIG
Air Flow Temperature °F	350°F
TO Chart Total Flow Min	112.4
TO Chart Total Press Min.	85.7
Engine Flow	117 PPM
Static Pressure Compressor Disc	
Engine Pressure	106 PSIA

☐ ACCEPTED ☐ REJECTED

OPERATOR

RECORDER: Richard D Friemel

REMARKS

AFTO FORM NOV 71 99

AFLC–WPAFB–NOV 71 15M

Foldout 2. AFTO Form 99.